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THE EFFECT OF WIND
ON
AIR QUALITY IN HAMILTON ONTARIO

BY

A.C. FARHANG

REPORT AQRB-83-001-M

JANUARY 1983

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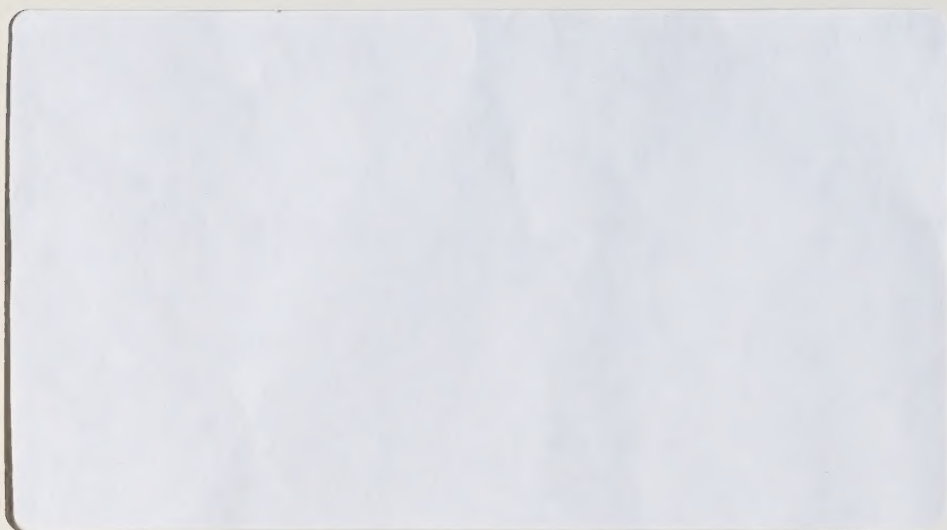


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Foreword and Acknowledgement

The author was awarded a one year Visiting Fellowship with Atmospheric Environment Service, Environment Canada, by the Natural Sciences and Engineering Research Council of Canada in September, 1981. Subsequently, he was assigned to the Urban Air Environment Group (UAEG), Department of Medicine, McMaster University, to make a contribution towards the meteorological aspect of their research project on "The Effect of Environmental Factors on the Respiratory Health of School Children in Hamilton" which had been in progress for more than two years.

The initial two months of the assignment were spent on familiarization with the research project, local climatology, and also sources of related data. This was later followed by a study on "Meteorology and Climatology of Hamilton (ONT.) and its Surroundings". The report was published by UAEG.

The present report is an investigation of the relationship between wind and the diffusion and transport of air pollutants in Hamilton. The study has mainly concentrated on particulate matter which is of major concern in Hamilton. An attempt has been made to locate the predominant sources in the city.

At this point the author would like to take this opportunity to express his sincere thanks to Professor C.H. Goldsmith,

Department of Clinical Epidemiology and Biostatistics, McMaster University, for his comments on statistical interpretation and general presentation; Dr. J.W.S. Young Acting Director, Air Quality and Inter-Environmental Research Branch, AES, for his interest and encouragement; Mr. T.R. Allsopp, Acting Chief, Scientific Services Division, AES, Ontario Region, for his comments on the report; Mr. P.J. Schaffer, head of the Systems Services Unit, and Mr. B. MacLachlan of the Systems Services Unit, both of the Air Quality and Meteorology Section, Air Resources Branch, Ontario Ministry of the Environment, for providing computational services; Mr. S. Toplack, UAEG project manager, for providing editorial assistance and office facilities; and Mrs. R. Capretta, UAEG project secretary who typed this report.

Ardeshir C. Farhang

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TOPOGRAPHY AND MORPHOLOGY*

Hamilton is located at the western corner of Lake Ontario (Figure 1). The Niagara Escarpment divides the city sharply into two levels, whose altitudes differ by more than 100 metres and, in some parts by about 150 metres. The lower city is a narrow strip of deep re-entrant valleys' the prominent ones are the southwest/northeast-oriented Dundas Valley to the west and the north/south aligned valley of Redhill Creek to the east.

The city itself covers an area of about 110 km² and has an approximate population of 300,000. The city has four major land uses. There is an identifiable sector of heavy industry concentrated along the southern shore of Hamilton Harbour. The major steel plants are located here, together with a number of associated industries. This industrial complex, especially the steel industry, which is a source of man-made heat and pollution in the area, affects various aspects of the local environment and, in particular, the atmospheric environment.

The main business district of Hamilton is located in the west-central part of the city, with some high-rise apartment buildings in the south of that area. The rest of the lower level of the city is occupied by a mixture of commercial and mainly residential properties plus some light industry concentrated around the main industrial zone. The upper level of the city is

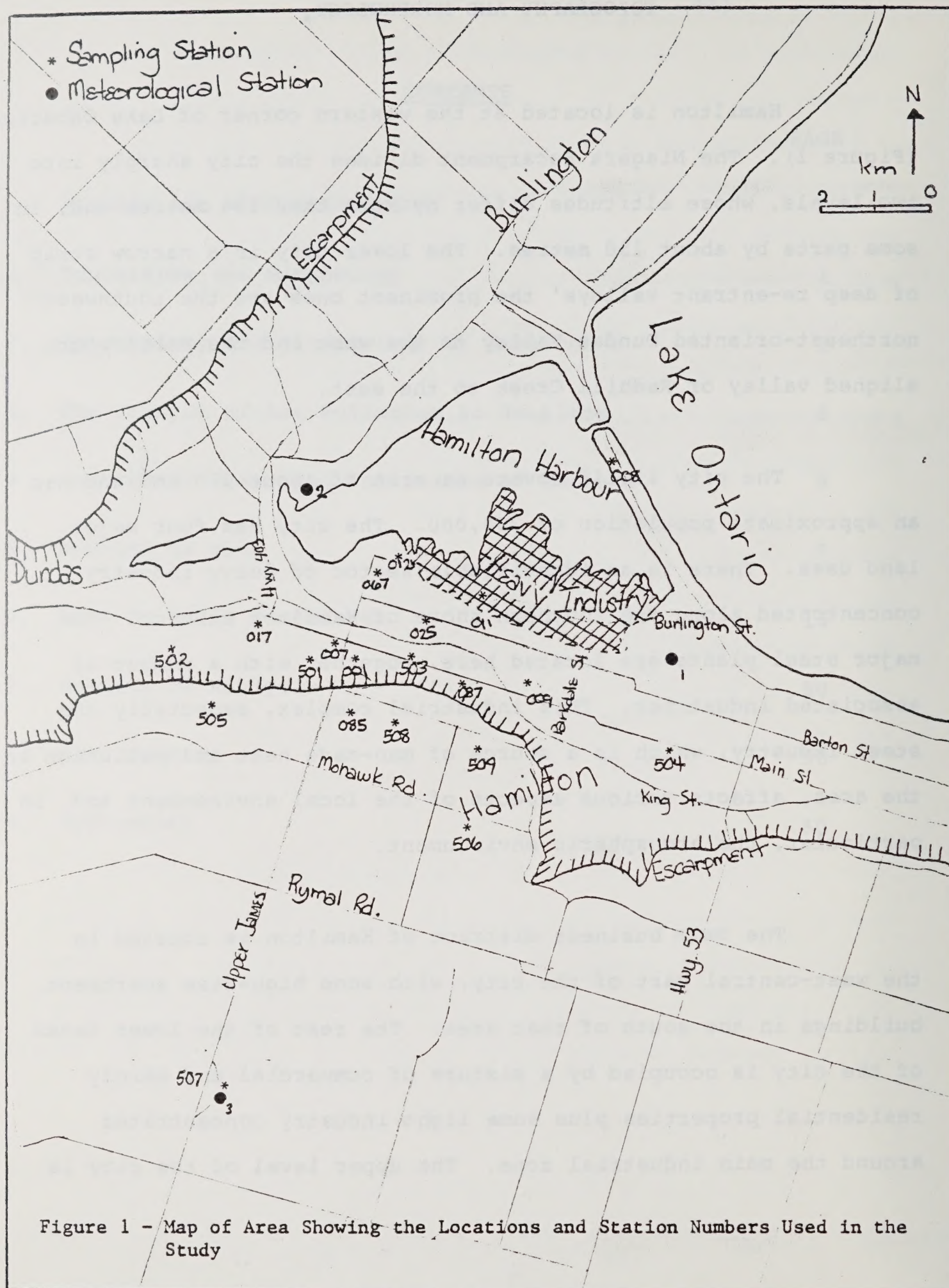


Figure 1 - Map of Area Showing the Locations and Station Numbers Used in the Study

mainly residential with some multi-storey apartment blocks and a cluster of light industry in the far end of the south-southeast limits of the city.

(*) This section has been extracted from (Farhang, 1982)

METEOROLOGY AND CLIMATOLOGY OF HAMILTON*

Being located at 43° N, 79° W, Hamilton and its surroundings have rather a continental climate with some modifications due to its proximity to Lake Ontario. The lake modifies, to some extent, both winter and summer extremes and provides additional moisture to intensify precipitating systems.

Hamilton has rainy weather (including trace) in more than half of the days of the year. On the average, the annual precipitation in the area is 806 mm (average is on the basis of the means of 12 climatological stations with their sampling periods ranging from 10 to 92 years), and has a fairly reliable regimen from month to month and from year to year. February is the driest month (average precipitation 53.5 mm), while August is the wettest month (average precipitation 75.7 mm).

The winter (December to February) precipitation comes mostly from frontal depression systems, and mainly in the form of snow. Spring precipitation is mainly frontal, with some due to convective activities. Most of the summer precipitation is relatively brief and showery, resulting from convective and

thunderstorm activities. During autumn, more cold air masses and frontal depressions approach the area, resulting in longer periods of precipitation.

The annual weather regimen is one of relatively warm humid summers to cold snowy winters. While the freezing point or below may occur now and then in November, a steep turn into well-below-freezing starts at the beginning of December, and remains there for three months. March temperatures average some fractions of a degree around the freezing point. The warmest months of the year are July and August with means of 20 degrees centigrade or slightly above it.

The annual mean temperature above the Niagara Escarpment (upper city) is up to about one degree centigrade lower than below the escarpment (lower city).

The dominant wind directions in Hamilton are southwesterly and westerly (on the basis of four local stations with sampling periods from 6 to 10 years). About 50 percent of the total annual wind frequency is from either of these two directions. The highest frequencies of these two directions occur in winter and the lowest in spring.

The next most predominant wind directions are northeasterly and easterly. Spring with about 30 percent has the highest frequency of NE + E flows, while winter with about 16 percent, has the lowest frequency of these flows. It should be

emphasized here, that these two directions coincide with the lake breeze circulation in Hamilton and also pass over the polluted heavy industrial zone, and therefore are the directions of main concern throughout the present report.

Lake breeze, which generally develops under weak geostrophic wind conditions on clear or relatively clear days, in response to differential heating over land and water surfaces, has rather a unique development in Hamilton. Steel making processes in the heavy industrial zone, by Hamilton Harbour, add substantial heat to the natural heat mechanism. As a result, lake breeze is established in almost eight months of the year from March to October, and gains in its maximum intensity in July and August. Land breeze, which is a reverse condition, forms at night, again in most of the months of the year, gaining its maximum intensity in July.

The lake and land breeze patterns are quite localized, and only occasionally extend beyond the Niagara Escarpment which is only about 3-8 km from the water body, to some distance to the south. During the lake breeze occurrences, or when the regional pattern is N - NE - E, the lower levels of the flow generally cannot cross the escarpment, and will be deflected clockwise from east to west over the city to be eventually channelled through Dundas Valley.

Altogether, the area is windy. Ideal calm conditions can

only rarely to established, whereas strong winds occur frequently, especially in winter.

(*) This section has been extracted from (Farhang 1982)

THE PROBLEM OF AIR POLLUTION IN HAMILTON

Air quality in Hamilton has improved significantly since 1970 in terms of long-term averages for most monitored pollutants. However, the main concern continues to be particulate matter. Suspended particulate levels dropped most perceptibly during the 1972-75 period. This improvement is attributable to the control programs instituted by major industries in conjunction with the Ontario Ministry of Environment (O.M.E.). Since 1975 though, levels have remained relatively stable and are still unsatisfactory in many areas of the city, especially near the heavy industry. However, the majority of the city does generally experience acceptable air quality. The soiling index shows a similar trend to suspended particulates, but dustfall levels have surprisingly shown no improvement at all during 1970's (O.M.E. Reports 1978 and 1980).

Three sources of particulates can be attributed to the problem in Hamilton"

- (a) Background source - This source is due to long and medium range diffusion and transport of particulate matter from

other areas to Hamilton region.

(b) Non-industrial fugitive source(s) - This is due to urban life, including such sources as roads and traffic, construction, and similar activities. In this report combined first and second sources will be referred to as "ambient background source".

(c) Industrial source - This is an area source of heavy industrial zone to the north of the city, by Hamilton Harbour. In fact, the industrial source is a combination of emissions from stacks, and industrial fugitive source(s) such as blow-off from stock-piles, unpaved areas, excavation and construction activities, material handling and road traffic, which due to the nature of the industrial zone have a very dynamic and active role. However it is this industrial source which should be considered the main cause of the particulates problem in Hamilton, particularly in the vicinity of the zone and in the downtown area.

Sulphur dioxide (SO_2) emissions in Hamilton stem mostly from industrial sources. Only a small portion is accounted for by fuel burning in domestic space heating (OME Report 1980). In any case, according to the same OME report, the annual, daily, and hourly levels of this pollutant have been generally acceptable in recent years, and below the objectives of OME.

METHODS OF MEASURING POLLUTANTS OF CONCERN*

Particulates are measured by three methods, each relating to a different size range. Dustfall jars measure heavy material generally greater than 10 microns in diameter. High volume samplers measure suspended particulates varying in size from submicron to 50 microns. Co-efficient of haze tape samplers measure mostly fine material from submicron to about 10 microns. Of these 3, data from the high volume sampler (suspended particulates in $\mu\text{g}/\text{m}^3$) and coefficient of haze tape sampler (soiling index in $\text{COH}_s/1,000$ feet) are of interest in the present study.

A high volume sampler draws a known volume of air through a preweighed filter for a 24-hour period (midnight to midnight). The exposed filter will be weighed again and the difference in conjunction with the known amount of air flow is expressed as concentration in micrograms per cubic metre.

In co-efficient of haze tape sampler method, air is drawn through a filter paper and the optical density of the soiled spot is measured by light transmittance. This sampler operates continuously and determines hourly or two-hourly average soiling values. Since the one and two-hour samplers do not show a good agreement, and it is believed that the one-hour values are more accurate, the data of those two stations which operate on an hourly basis have been used in this study.

In order to measure the levels of sulphur dioxide, an air sample is drawn through a detection cell containing an anode, a cathode and a reference electrode immersed in a buffered solution of potassium bromide. The sample gas reacts with bromine to cause an electro-chemical imbalance in the cell which is proportional to the SO_2 concentration.

(*) The information regarding the methods has been extracted from (OME 1978 and OME 1980).

SOURCES OF DATA

There are two high-volume (Hi-Vol) sampling networks in Hamilton measuring total suspended particulates. One is run by OME, and the other run by McMaster University, Department of Medicine, Urban Air Environment Group (UAEG). While the first network is being operated as part of the provincial monitoring programs, the second one is experimental, established temporarily for research studies.

In the present report, data from 11 OME, and 9 from UAEG Hi-Vol stations have been used. The selection of the stations was made on the basis of their locations and periods of data coverage. Since the stations were not established simultaneously, it was attempted to select those stations that covered a 3-year period (1979-1981) of data. However, some of the selected stations still

do not cover the full desired period, lacking about 3 months of values either at the beginning of 1979 or the end of 1981. Except for two OME stations which have daily readings of suspended particulates, the rest run on a once every sixth day cycle.

OME also runs two hourly co-efficient of haze tape samplers at its Barton/Sanford, 025 and North Park, 008 Sites (See Fig. 1) . At the same stations, sulphur dioxide(SO_2) analyzers are being operated continuously, with means calculated hourly. These two sets of data from each of the two stations, covering the period of 1979-81, were also used in the present report.

Meteorological data, hourly wind speeds and directions were obtained from Mount Hope weather station and also the OME met tower. The former was considered to represent the wind conditions at the upper city, while the latter represent the lower city conditions. Daily precipitation was obtained again from Mount Hope for the upper city and from the Royal Botanical Gardens (R.B.G.) weather station for the lower city. This selection was made on the merit of the locations of the stations and in accordance with a study on meteorology of the area (Farhang, 1982).

Table 1 shows the names and station numbers, elements measured and type of measurements at each station. UAEG stations are indicated by (*). In Fig 1., using the station numbers, the location of each station is indicated.

Table 1 - Sampling and Meteorological Stations Used in the Study

PERIOD: 1979-1981

NO.	STATION NAME AND NUMBER	ELEMENTS MEASURED	TYPE OF MEASUREMENT
1	OME Met Tower , 1	Wind Speed & Direction	hourly
2	Royal Botanical Gardens , 2	Precipitation	daily
3	Hughson/Hunter, 001	Total Suspended Particulates (TSP)	Once (24 hrs) every 6 day cycle
4	City Hall, 007	TSP	Once (24 hrs) every 6 day cycle
5	North Park, 008	TSP SO ₂ Soiling Index (COH)	daily hourly hourly
6	Kenilworth, 009	TSP	Once (24 hrs) every 6 day cycle
7	Burlington/Leeds, 011	TSP	Once (24 hrs) every 6 day cycle
8	Burlington/Wellington, 012	TSP	Once (24 hrs) every 6 day cycle
9	Chatham/Frid, 017	TSP	Once (24 hrs) every 6 day cycle
10	Barton/Sanford, 025	TSP SO ₂ Soiling Index (COH)	daily hourly hourly
11	450 Hughson St. N., 067	TSP	Once (24 hrs) every 6 day cycle
12	Cumberland, 087	TSP	Once (24 hrs) every 6 day cycle
13	Aberdeen, 501 *	TSP	Once (24 hrs) every 6 day cycle
14	Witney/Rifle Range, 502 *	TSP	Once (24 hrs) every 6 day cycle

continued.....

TABLE 1 - continued

NO.	STATION NAME AND NUMBER	ELEMENTS MEASURED	TYPE OF MEASUREMENT
15	Cathedral, 503 *	TSP	Once (24 hrs) every 6 day cycle
16	Red Hill Creek, 504 *	TSP	Once (24 hrs) every 6 day cycle
	<u>UPPER CITY</u>		
17	Mount Hope Weather Stn., 3	Wind Speed and Direction Precipitation	hourly daily
18	Mountain Police, 085	TSP	Once (24 hrs) every 6 day cycle
19	San Diego, 505 *	TSP	Once (24 hrs) every 6 day cycle
20	Upper Ottawa, 506 *	TSP	Once (24 hrs) every 6 day cycle
21	Mount Hope, 507 *	TSP	Once (24 hrs) every 6 day cycle
22	Upper Wentworth, 508 *	TSP	Once (24 hrs) every 6 day cycle
23	Highview, 509 *	TSP	Once (24 hrs) every 6 day cycle

*: Stations run by McMaster University, U.A.E. Group. See Figure 1

DATA ANALYSIS PROCEDURES

Suspended Particulates

It is clear that in any air pollution study of the present type, the removal processes such as rainout, washout, and sedimentation introduce a large degree of variability in the analysis. In this study it was found useful to remove, more or less, the effect of precipitation (washout) on the analysis, by excluding the data measured during days with precipitation >1.00 mm. This exclusion has been taken into account for any suspended particulates analysis in the study.

The reason for excluding only days with precipitation >1.00 mm is that Hamilton has nearly 200 rainy (including trace) days annually, and in 18 out of 20 stations, measurements of suspended particulates have been made on the basis of once every sixth day cycle. As a result, excluding all days with any amount of precipitation from analysis would have left little or no data to analyse statistically. However, since suspended particulates data, and also precipitation data used in this study, are both daily values, it can be expected that daily precipitation of ≤ 1.00 mm has a minor effect on removal processes. Generally speaking, ≤ 1.00 mm precipitation will take a much shorter period than 24 hours to fall.

In the analysis of suspended particulates data, 3 procedures were employed which will be explained here, and the results will be discussed in the next section.

I - Isopleths of Suspended Particulates Under Two Different Wind Regimens

The high-volume sampler yields a reliable weight measurement (in $\mu\text{g}/\text{m}^3$) of particulate loading. However, because the sample is accumulated over 24 hours, there are some difficulties in interpreting the results in terms of meteorological elements of wind speed and direction which are measured hourly. Although correlating the daily prevailing wind direction with daily suspended particulates may be a useful measure, the result is not conclusive. A few hours loading associated with the wind from a certain sector, may greatly exceed that of the remaining day with prevailing wind direction. In order to overcome this uncertainty, the procedure used by Stewart and Matheson (1968), and by Munn et al. (1969) and Munn (1974) was adopted in this report.

Only those samples were considered that had been taken on days, when during the entire 24-hour of sampling period the wind had blown either from the northerly sector (NNW-E, $327^\circ - 101^\circ$) or from the southerly sector (SSE - W, $147^\circ - 281^\circ$). The selection of these two sectors was on the basis of local topography and

morphology, known pollution sources, and sea and land breeze circulations (see Farhang, 1982).

Arithmetic and geometric means of suspended particulate loadings were computed for both of these wind groupings and precipitation ≤ 1.00 mm for all 20 stations. Table 2 shows the detailed results. On the basis of these results, isopleths of mean values were drawn (Fig 2-5).

II - Correlation coefficients Between particulate Loadings and Wind Direction Frequencies

The product moment correlation coefficient (r) is a measure of linear relationship and is invariant to the units of values correlated.

Using a modified computer program (Air Resources Branch, OME) to exclude days with precipitation > 1.00 mm, correlation coefficients between daily wind direction frequencies and daily suspended particulate loadings were computed. In this program, daily distribution of wind direction has been defined as the total number of times out of the 24 hourly readings in a sampler day that wind has blown from a specified direction. The procedure has been explained in more detail by Samson et al. (1975). Table 3 shows the results of this computation for all 20 stations and 16

TABLE 2 Arithmetic and geometric means (in $\mu\text{g}/\text{m}^3$) and also geom. standard deviations of total suspended particulates during the days when precipitation has been ≤ 1.00 mm and wind directions in 24 hours have been 100% either from NNW-E($327-101^\circ$) or SSE-W($147-281^\circ$). Period: 1979-1981

NO.	STATION NAME AND NUMBER	Wind directions in 24 hours 100% from NNW-E and precipitation ≤ 1.00 mm				Wind directions in 24 hours 100% from SSE-W and precipitation ≤ 1.00 mm			
		NO. OF SAMPLES (days)	ARITHMETIC MEAN	GEOMETRIC MEAN	GEO. STAND. DEVIATION	NO. OF SAMPLES (days)	ARITHMETIC MEAN	GEOMETRIC MEAN	GEO. STAND. DEVIATION
	LOWER CITY								
1	Hughson/Hunter, 001	10	108	105	1.3	25	71	66	1.5
2	City Hall, 007	10	98	91	1.5	26	55	52	1.4
3	North Park, 008	42	57	55	1.4	124	155	144	1.5
4	Kenilworth, 009	9	93	88	1.6	27	62	58	1.5
5	Burlington/Leeds, 011	7	196	190	1.4	28	113	108	1.3
6	Burlington/Wellington, 012	9	94	93	1.2	26	75	72	1.4
7	Chatham/Frid, 017	8	111	100	1.5	27	110	98	1.6
8	Barton/Sanford, 025	44	168	151	1.7	120	92	83	1.5
9	450 Hughson St. N., 067	8	93	85	1.5	27	74	70	1.4
10	Cumberland, 087	9	95	86	2.0	22	62	58	1.4
11	Aberdeen, 501	10	55	53	1.5	28	44	39	1.7
12	Whitney/Rifle Range, 502	8	66	60	1.7	25	51	46	1.7
13	Cathedral, 503	10	98	92	1.5	23	67	60	1.6
14	Red Hill Creek, 504	11	42	39	1.5	24	38	34	1.7
	UPPER CITY								
15	Mountain Police, 085	5	87	85	1.3	21	67	62	1.5
16	San Diego, 505	7	47	42	2.0	22	50	47	1.5
17	Upper Ottawa, 506	5	44	42	1.3	28	46	43	1.5
18	Mount Hope, 507	7	38	35	1.6	26	51	48	1.5
19	Upper Wentworth, 508	6	66	62	1.5	22	53	48	1.7
20	Highview, 509	5	66	65	1.2	24	56	53	1.5

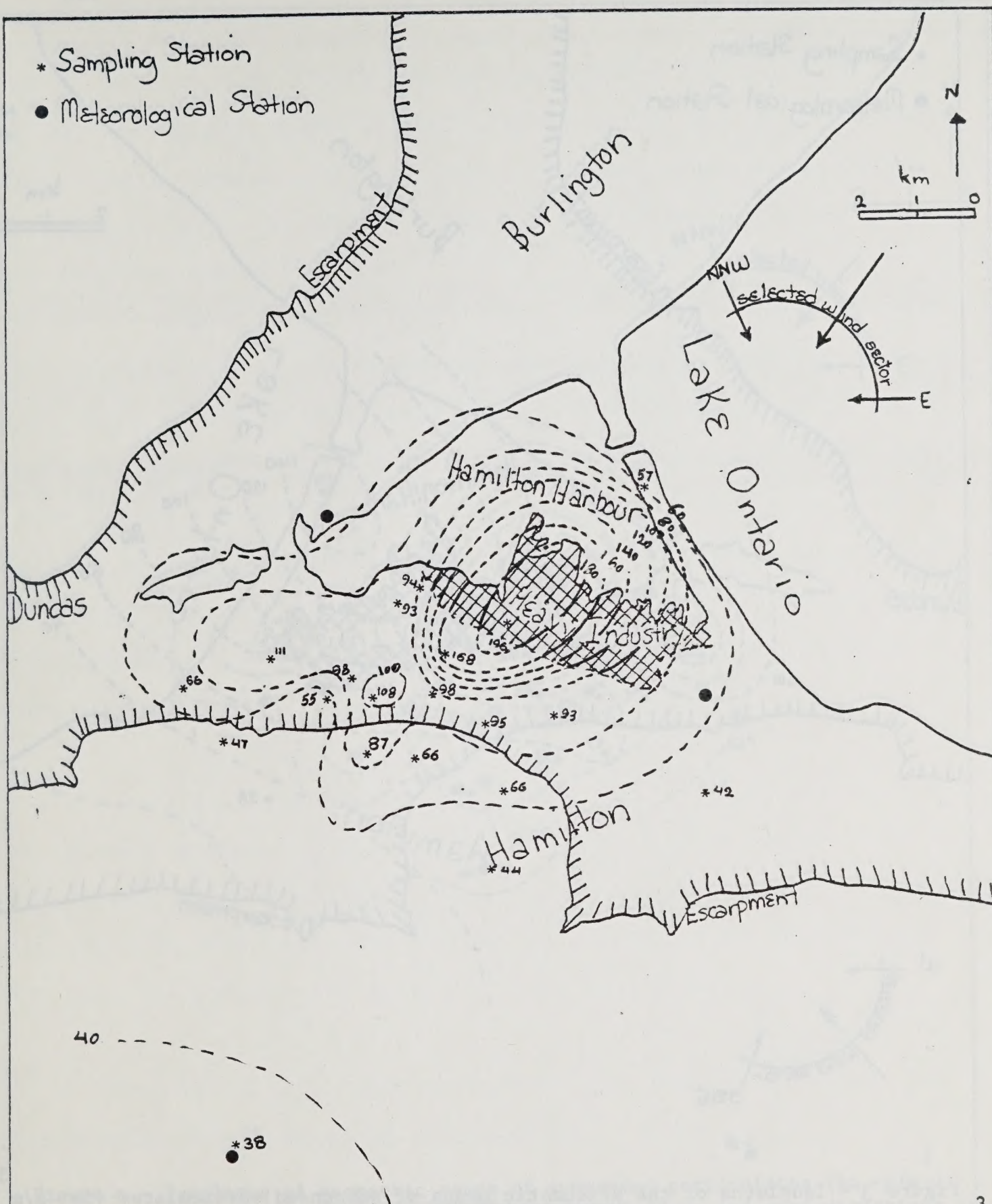


Figure 2 - Isopleths of the arithmetic means of suspended particulates (in $\mu\text{g}/\text{m}^3$) for days when precipitation has been ≤ 1.00 mm and wind directions in 24 hours have been 100% from NNW-E (327° - 101°). Period 1979-81

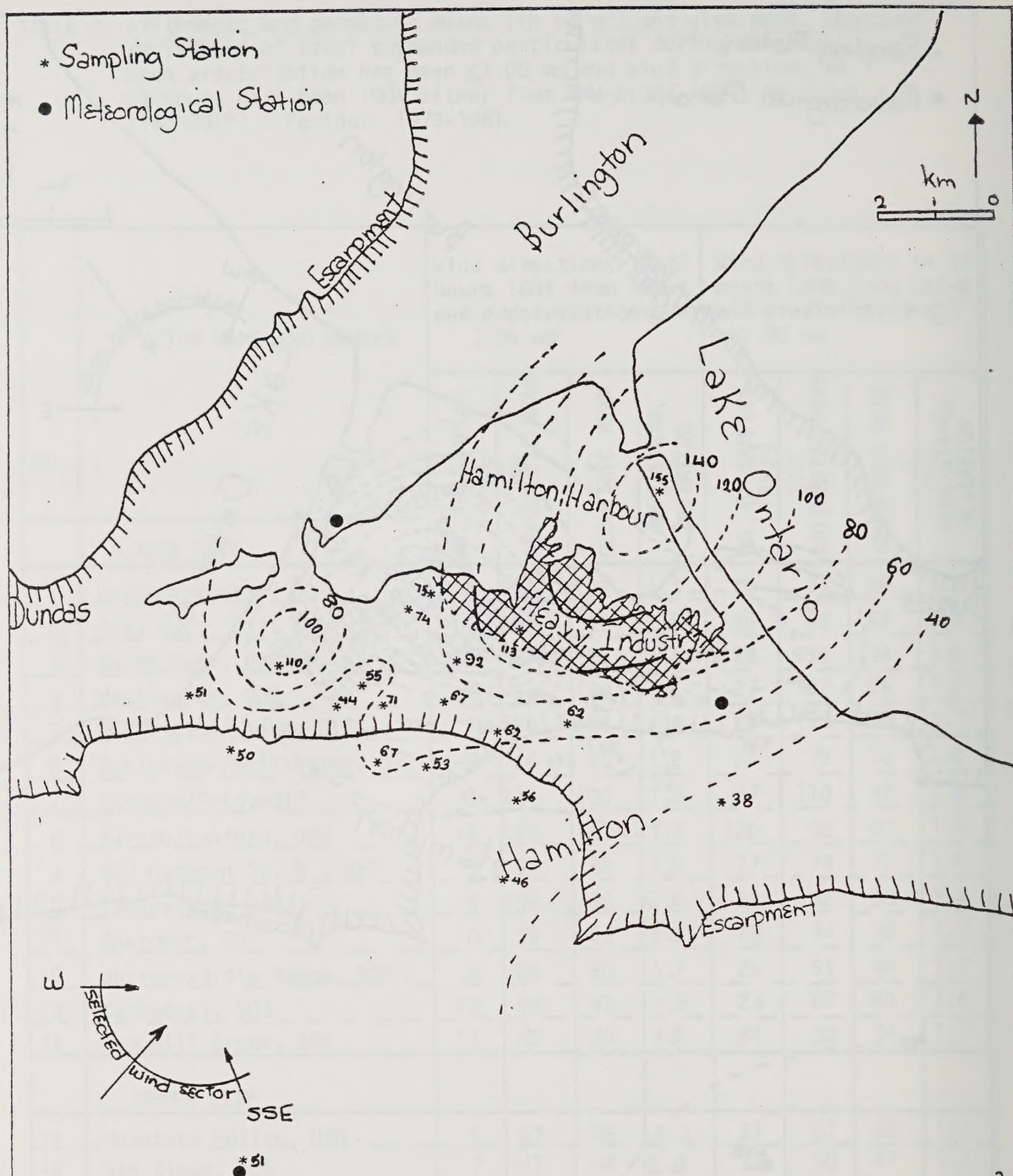


Figure 3 - Isopleths of the arithmetic means of suspended particulates (in $\mu\text{g}/\text{m}^3$) for days when precipitation has been ≤ 1.00 mm and wind directions in 24 hours have been 100% from SSE-W (147° - 281°). Period 1979-81

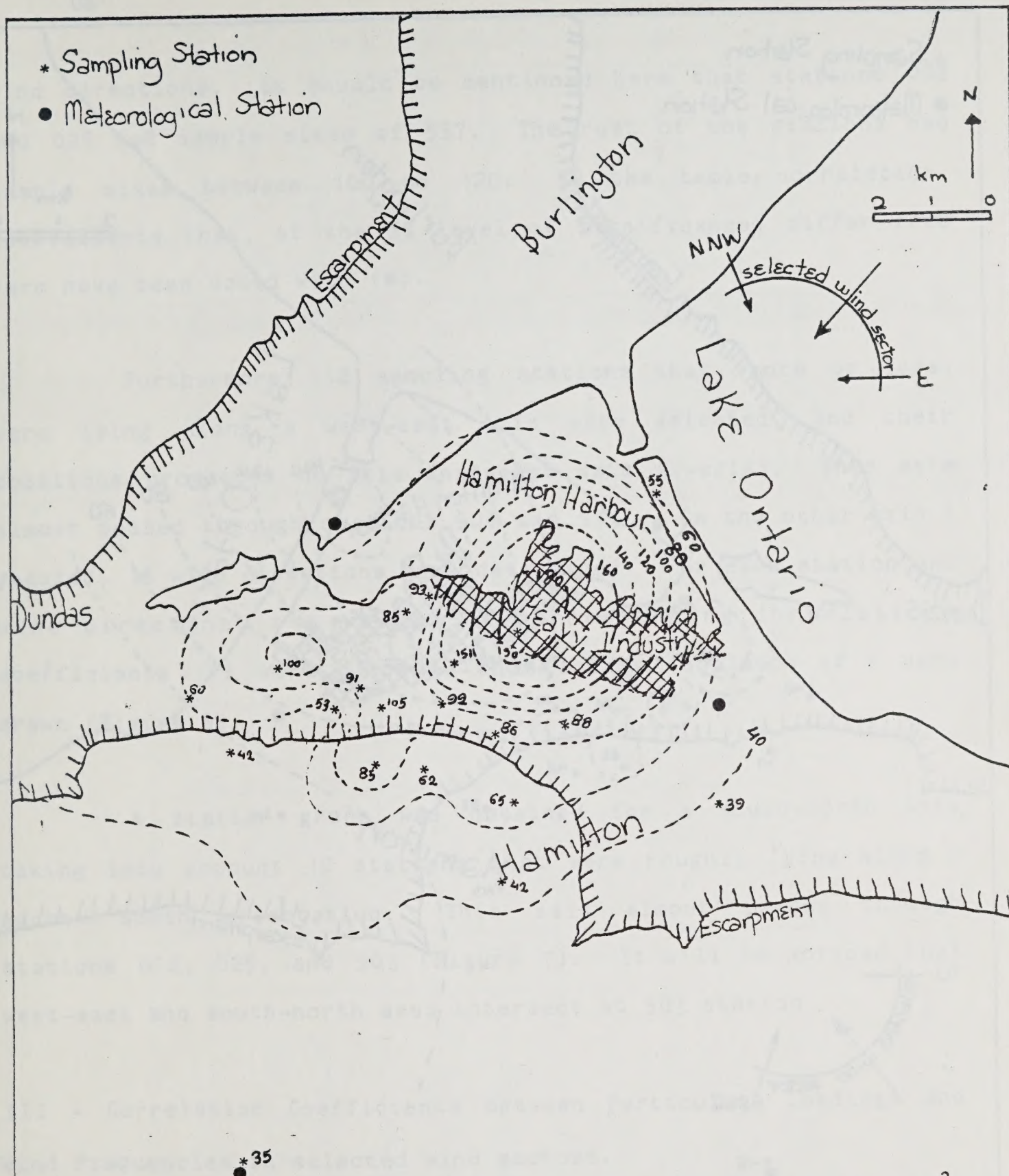
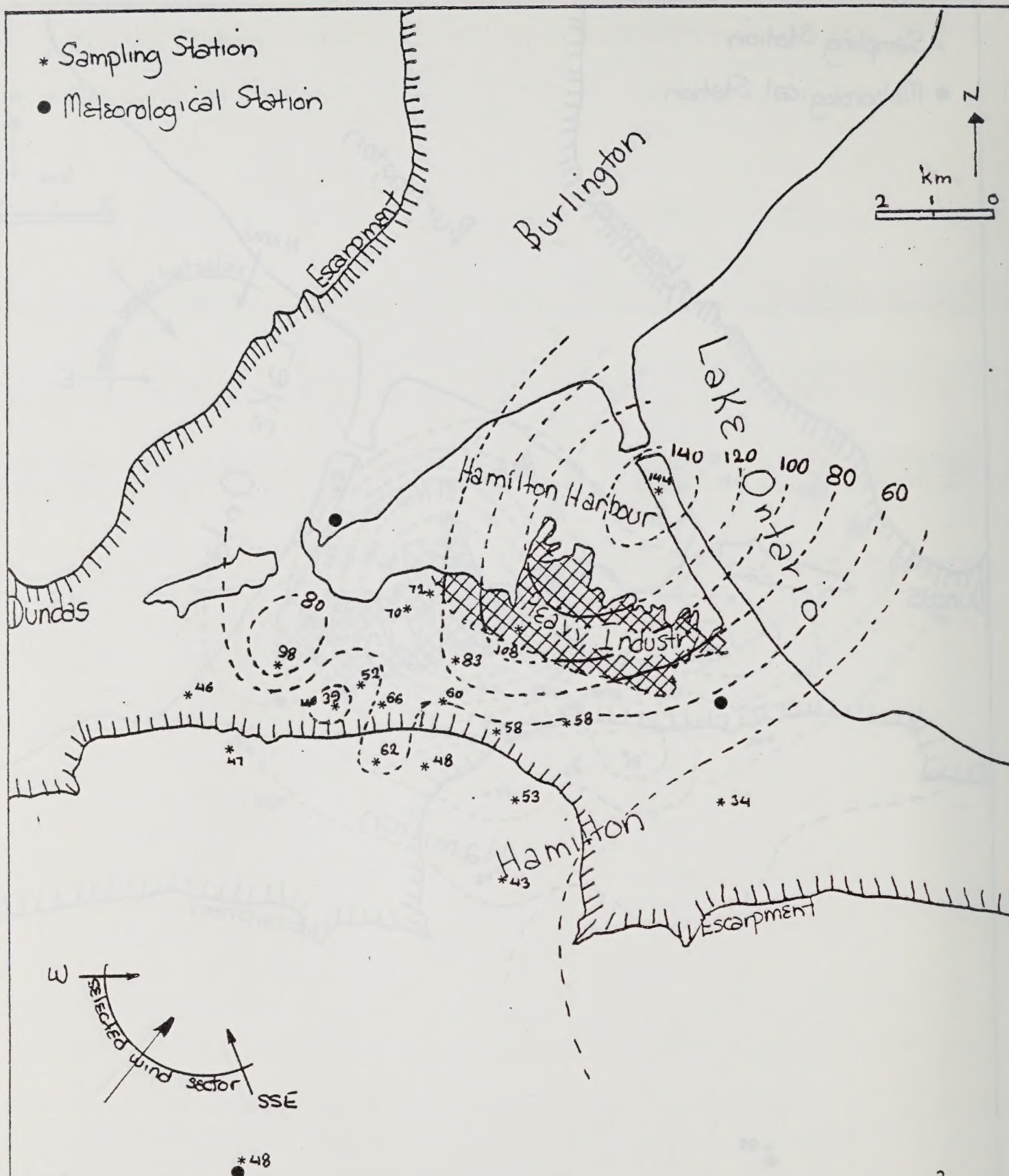


Figure 4 - Isopleths of geometric means of suspended particulates (in $\mu\text{g}/\text{m}^3$) for days when precipitation has been ≤ 1.00 mm and wind directions in 24 hours have been 100% from NNW-E ($327^\circ - 101^\circ$). Period 1979-81



3

Figure 5 - Isopleths of geometric means of suspended particulates (in $\mu\text{g}/\text{m}^3$) for days when precipitation has been ≤ 1.00 mm and wind directions in 24 hours have been 100% from SSE-W ($147^\circ - 281^\circ$). Period 1979-81

wind directions. It should be mentioned here that stations 008 and 025 had sample sizes of 587. The rest of the stations had sample sizes between 100 to 120. In the table, correlation coefficients that, at the 5% level of significance, differ from zero have been noted with (●).

Furthermore, 12 sampling stations that, more or less, were lying along a west-east axis were selected, and their positions projected on this west-east axis (x-axis). This axis almost passed through stations 502 and 503. On the other axis (y-axis), 16 wind directions were determined. For each station and wind direction, the values of corresponding correlations coefficients (r) were plotted, and finally isopleths of r were drawn (Figure 6).

A similar graph was obtained for a south-north axis taking into account 10 stations that were roughly lying along a north - south orientation. This axis almost passed through stations 012, 025, and 503 (Figure 7). It will be noticed that west-east and south-north axes intersect at 503 station.

III - Correlation Coefficients Between Particulate Loadings and Wind Frequencies in selected wind sectors.

In order to have a better understanding of the effect of selected wind direction groups (NNW-E and SSE-W) on particulate loadings, the correlation coefficients between these two elements

TABLE 3 Correlation Coefficients Between Daily Amount of Total Suspended Particulates and Daily Wind Direction Frequencies for Days When Precipitation Has Been ≤ 1.00 mm. Correlation Coefficients That at the 5% Level of Significance Differ From Zero are Noted with (●).

NO.	STATION NAME AND NO.	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
1	Hughson/Hunter, 001	● .20	● .31	● .35	● .37	● .34	.18	.10	.02	.02	-.05	.12	● -.21	● -.25	● -.23	● -.19	● -.06	.12
2	City Hall, 007	● .27	● .34	● .38	● .47	● .34	.09	.12	.05	-.06	-.09	.20	● -.28	● -.23	● -.17	● -.13	● -.06	.17
3	North Park, 008	● -.33	● -.27	● -.30	● -.27	● -.25	.12	-.04	+.08	.19	.42	.49	● .32	● -.07	● -.17	● -.18	● -.26	-.08
4	Kenilworth, 009	● .32	● .27	● .29	● .40	● .36	.05	.10	.04	.08	-.01	.22	● -.31	● -.33	● -.19	● 0.08	.19	.18
5	Burlington/Leeds, 011	● .25	● .34	● .43	● .50	● .34	.06	.03	-.01	00	-.24	.26	● -.19	● -.18	● -.14	● -.02	+.02	.20
6	Burlington/Wellington, 012	.09	.06	.29	.39	● .31	.18	.12	.04	.12	-.05	.18	-.11	-.21	-.23	-.01	-.09	.22
7	Chatham/Frid, 017	.06	.09	.19	.34	.17	.08	.05	-.02	.05	.01	.07	-.09	-.25	-.27	-.14	-.08	.17
8	Barton/Sanford, 025	● .15	● .40	● .43	● .40	● .21	.15	.13	.07	.04	-.01	.12	● -.18	● -.28	● -.28	● -.25	● -.15	.33
9	450 Hughson St. N., 067	.16	.03	.21	.37	● .34	.15	.05	.06	.10	.09	.01	-.10	-.30	-.32	-.18	-.09	.13
10	Cumberland, 087	● .24	● .32	● .27	● .24	● .29	.21	.07	.11	.10	-.05	.18	-.24	-.23	-.22	-.07	.08	.26

continued.....

TABLE 3 - continued

NO.	STATION NAME AND NO.	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
11	Aberdeen, 501	.11	.20	.38	.35	.26	.05	.07	.07	.08	.00	-.09	-.25	.28	-.11	-.08	-.12	.32
12	Whitney/Rifle Range, 502	.21	.20	.19	.36	.25	.02	.04	.13	.10	.07	-.00	-.22	-.32	-.17	-.11	-.11	.35
13	Cathedral, 503	.21	.32	.40	.29	.33	.08	.01	.06	.09	.02	-.12	-.27	-.28	-.20	-.13	-.09	.36
14	Red Hill Creek, 504	.09	.15	.14	.19	.14	.05	.04	.10	.10	.13	-.06	-.25	-.28	-.06	-.06	-.08	.22
15	Mountain Police, 085	-.02	.12	.25	.23	.18	.17	.18	.16	.20	.01	.05	-.23	-.26	-.25	-.18	-.07	.27
16	San Diego, 505	-.05	.01	.26	.28	.26	.07	.05	.18	.24	.12	.11	-.12	-.39	-.31	-.16	-.02	.03
17	Upper Ottawa, 506	.02	.05	.23	.20	.20	.07	.04	.15	.17	.17	.14	-.19	-.35	-.27	-.11	-.05	.07
18	Mount Hope, 507	-.04	.03	.12	.10	.11	-.03	.07	.01	.26	.22	.16	-.09	-.22	-.23	-.19	-.05	.08
19	Upper Wentworth, 508	-.04	.09	.40	.32	.28	.23	.12	.23	.22	.24	.02	-.19	-.41	-.31	-.22	-.12	.09
20	Highview, 509	.08	.17	.33	.21	.13	.07	.08	.18	.18	.14	.07	-.14	-.36	-.32	-.23	.07	.10

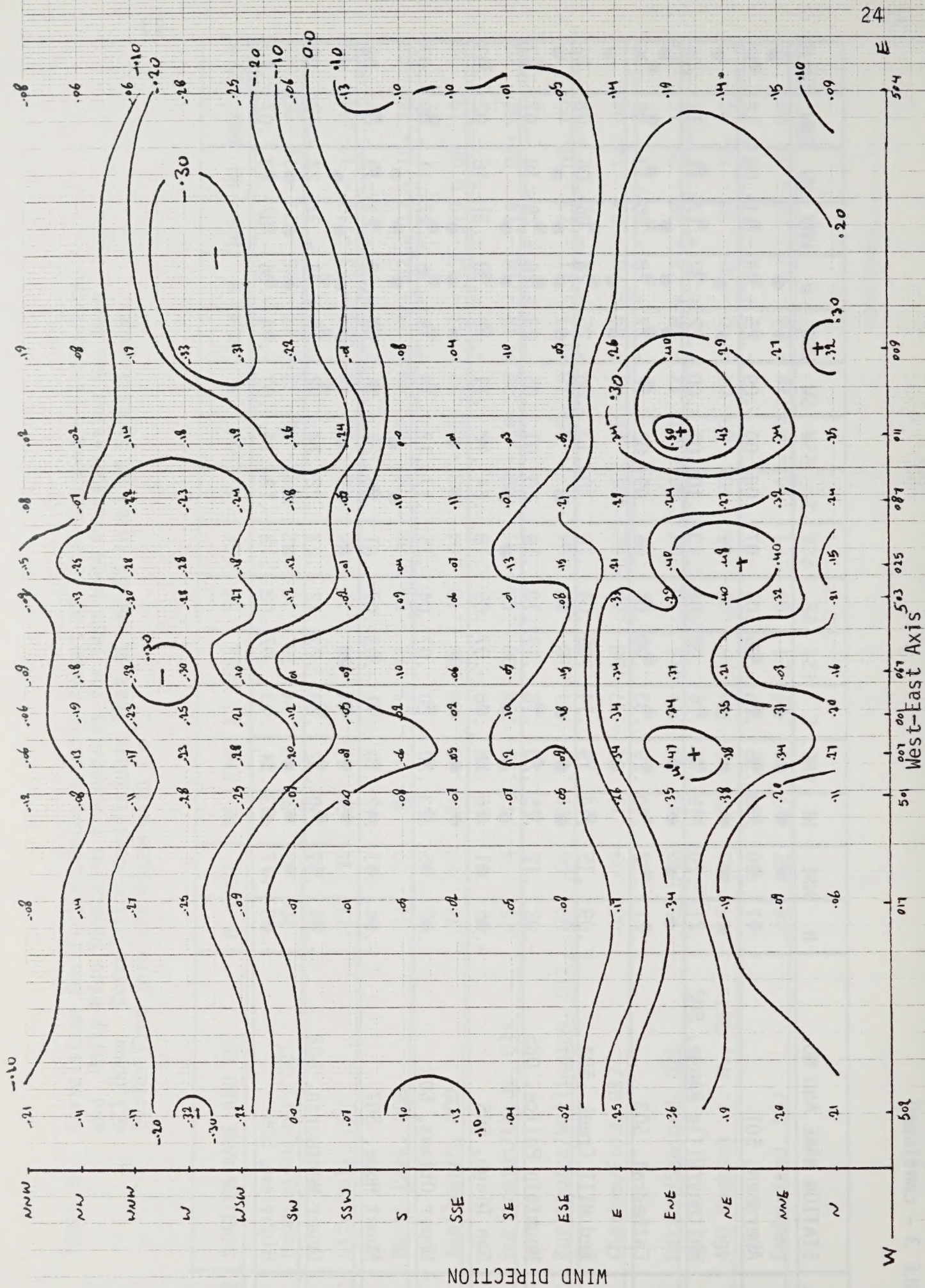


FIGURE 6 - Isopleths of correlation coefficients between daily wind direction frequencies and daily particulate loadings (precipitation ≤ 1.00 mm) for those sampling stations which are more or less located along a west-east direction.

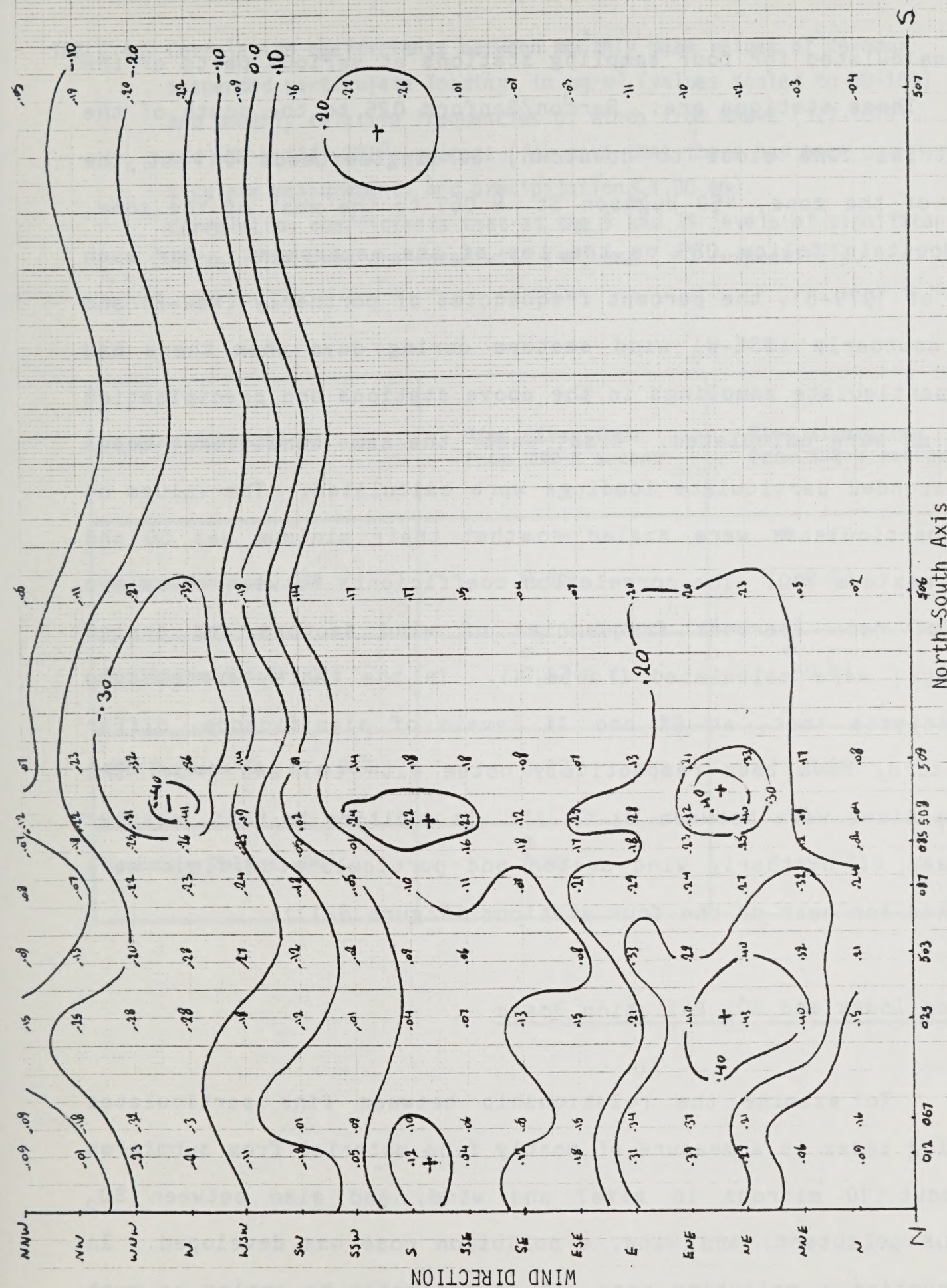


FIGURE 7 - Isopleths of correlation coefficients between daily wind direction frequencies and daily particulate loadings (precipitation < 1.00 mm) for those sampling stations which are more or less located along a north-south direction.

were calculated for four sampling stations at various parts of the city. These stations are: Barton/Sanford 025 to the south of the industrial zone close to downtown, Burlington/Leeds 011 at the heart of the zone, 450 Hughson St. N 067 to the west of the zone, and Mountain Police 085 on the top of the escarpment. For each month of 1979-81, the percent frequencies of northerly (NNW-E) and also southerly (SSE-W) wind sectors during days when there had been particulate samplings in the above stations and precipitation ≤ 1.00 mm were calculated. Also, under the same conditions, means of suspended particulate loadings were calculated. The values of mean particulates were scaled so that their minimum was 00 and their maximum 100. The correlation coefficients between these two sets of data (percent frequencies of wind sectors and scaled loadings) were calculated (Table 4). In the table, correlation coefficients that, at 5% and 1% levels of significance, differ from zero, have been respectively noted with (●) and (*). The sample sizes were between 23 to 31. In addition to that, scatter diagrams of northerly wind sector and particulate loadings were obtained for each of the four stations (Figure 8-11).

Soiling Index and SO₂ Pollution Roses

To examine the relationship between fine particulates (soiling index is a measure of mostly fine material from submicron to about 10 microns in size) and wind, and also between SO₂ (gaseous pollutant) and wind, a pollution rose was developed. In constructing a pollution rose, it is desirable to employ as much

TABLE 4 - Correlation coefficients between monthly mean values of 24-hour suspended particulate loadings in $\mu\text{g}/\text{m}^3$ (values scaled to 00-100) and monthly relative frequencies of winds from NNW-E ($327-101^\circ$) and SSE-W ($147-281^\circ$) sectors (for days that there had been particulate measurements and precipitation ≤ 1.00 mm). Correlation coefficients that at the 5 and 1% levels of significance differ from zero are noted with (●) and (*) respectively.

Station Name and No.	Wind directions from NNW-E sector	Wind directions from SSE-W sector
Barton/Sanford, 025	● * 0.68	● * -0.60
Burlington/Leeds, 011	● * 0.67	● * -0.54
450 Hughson St. N., 067	0.27	-0.08
Mountain Police, 085	● 0.42	-0.18

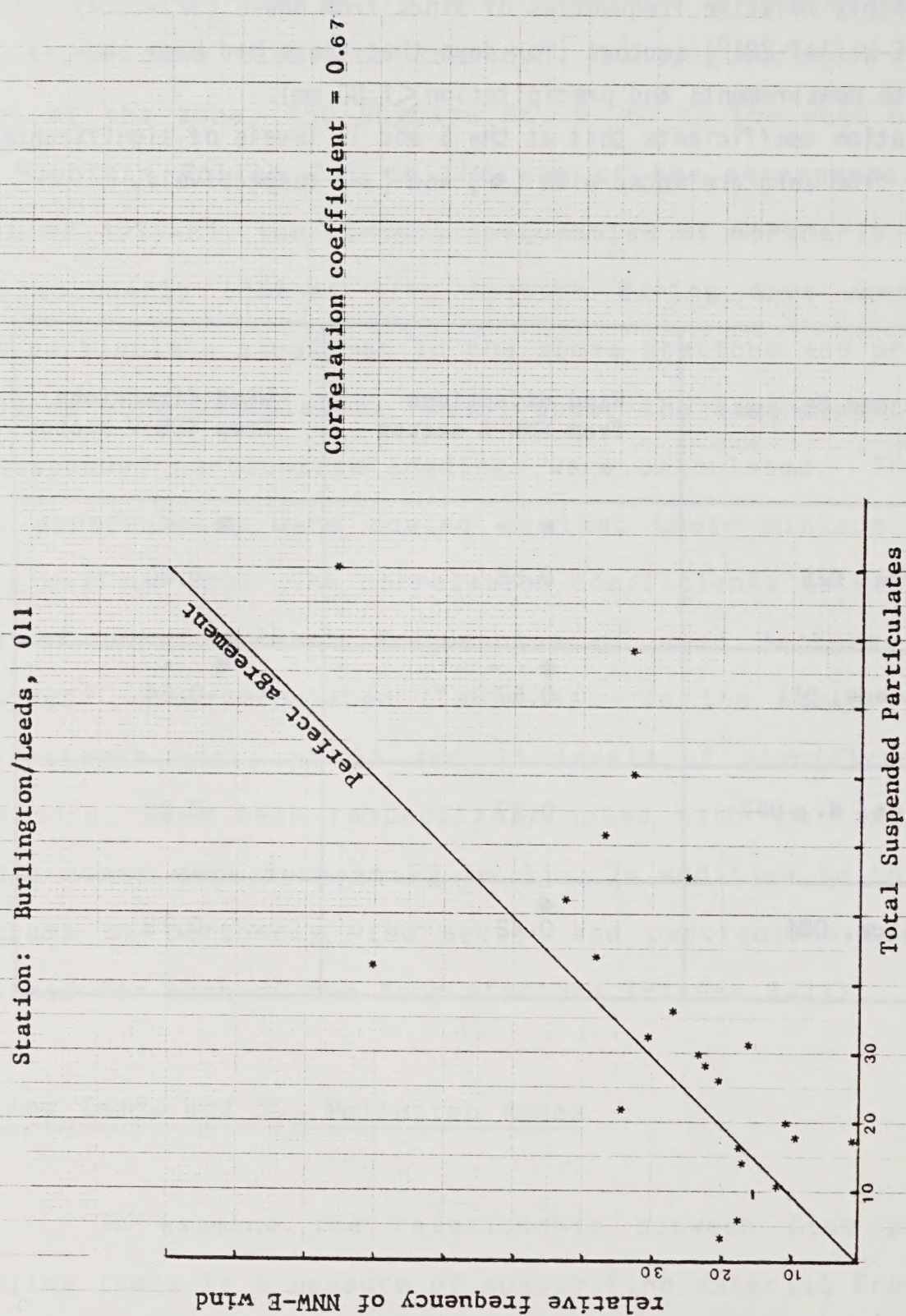


FIGURE 8 - Scatter diagram of monthly mean values of 24-hour suspended particulate loadings in $\mu\text{g}/\text{m}^3$ (values scaled to 00-100), versus monthly relative frequencies of winds from NNW-E (327-1010) sector (for days that there had been particulate measurements and precipitation ≤ 1.00 mm).

Station: Barton/Sanford, 025

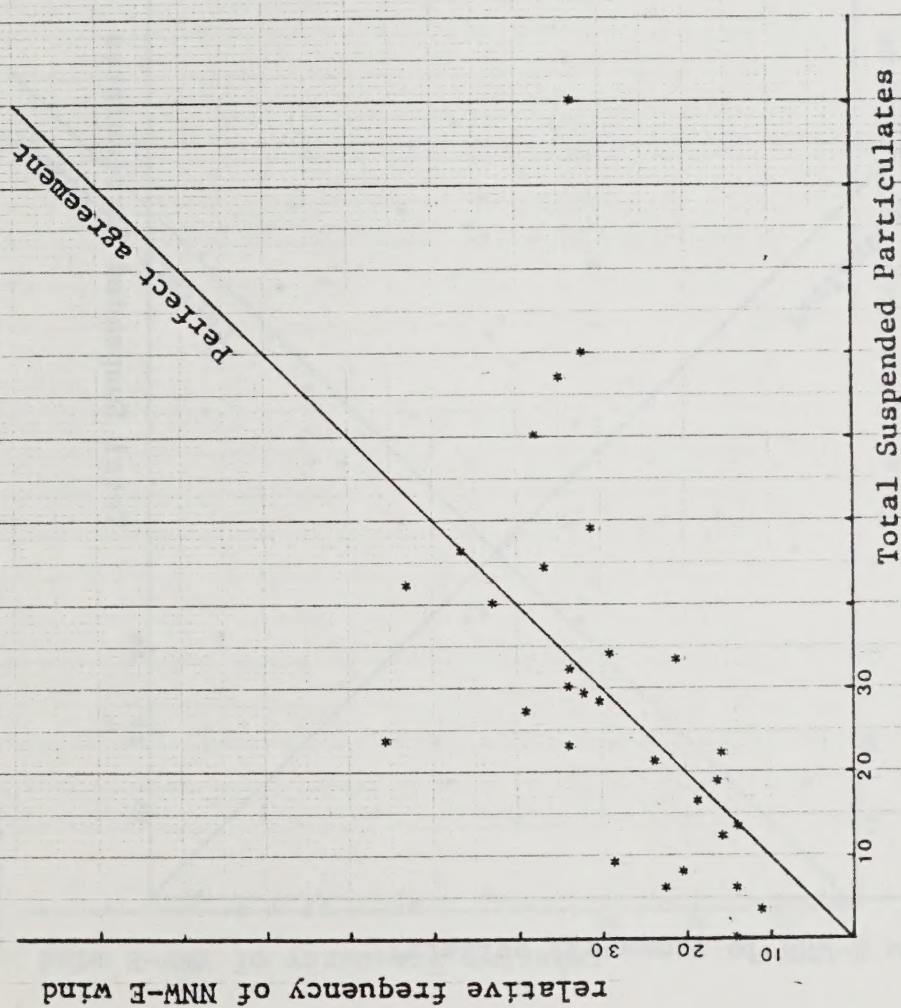


FIGURE 9 - Scatter diagram of monthly mean values of 24-hour suspended particulate loadings in $\mu\text{g}/\text{m}^3$ (values scaled to 00-100), versus monthly relative frequencies of winds from NNW-E (327-1010) sector (for days that there had been particulate measurements and precipitation ≤ 1.00 mm).

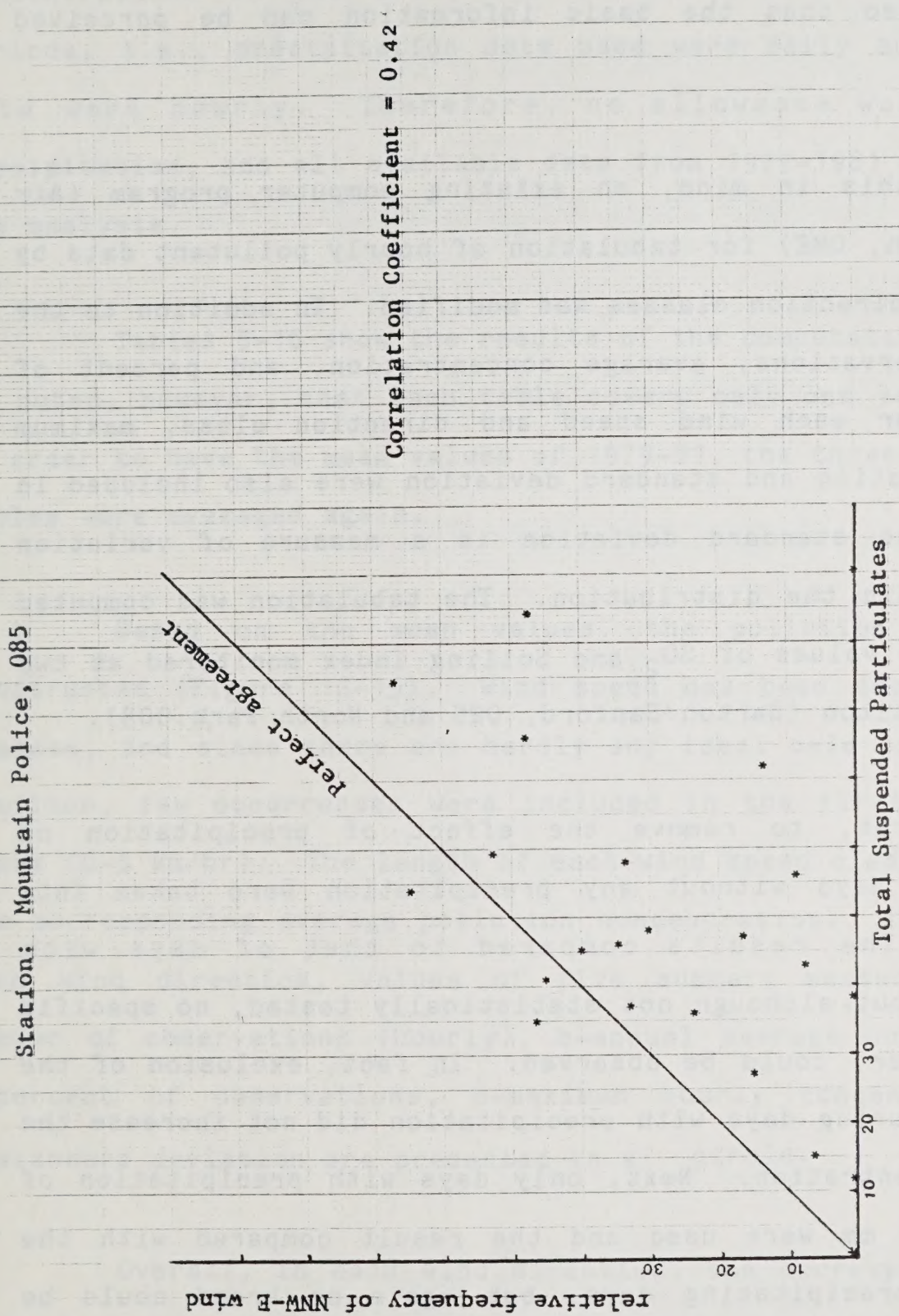


FIGURE 11 - Scatter diagram of monthly mean values of 24-hour suspended particulate loadings in $\mu\text{g}/\text{m}^3$ (values scaled to 00-100), versus monthly relative frequencies of winds from NNW-E (327-1010) sector (for days that there had been particulate measurements and precipitation ≤ 1.00 mm).

information as possible, and yet, display it in the simplest possible way, so that the basic information can be perceived easily.

With this in mind, an existing computer program (Air Resources Branch, OME) for tabulation of hourly pollutant data by wind speed and direction classes was modified. In addition to the number of observations, average concentration, and percent of observations for each wind speed and direction class, maximum hourly concentration and standard deviation were also included in tabulation. The standard deviation is a measure of variation about mean within the distribution. The tabulation was computed for hourly mean values of SO_2 and Soiling Index monitored at two stations in Hamilton (Barton/Sanford, 025 and North Park, 008).

At first, to remove the effect of precipitation on analysis, only days without any precipitation were taken into tabulation. The results compared to that of days with precipitation but, although not statistically tested, no specific trend, whatsoever, could be observed. In fact, exclusion of the data obtained during days with precipitation did not increase the levels of concentration. Next, only days with precipitation of more than 1.00 mm were used and the result compared with the result of no precipitating days, but again no trend could be noticed. In other words, the removal effect of precipitation could not be noticed in either of these analysis. The reasons may be attributed to: (a) less pronounced removal effect of

precipitation on fine particles, (b) the low levels of SO_2 concentrations in the area, and (c) difference in measurement periods, i.e., precipitation data used were daily but pollutant data were hourly. Therefore, no allowance was made for precipitation, and all available data from 1979-1981 were used in the analysis.

Tables 5-16 show the results of the computation. It will be noted, however, that each table covers only one year of data. In order to have the mean values of 1979-81, the three single year tables were averaged again.

Based on the mean values, the pollution roses were constructed (Figure 12-15). Wind speed has been grouped into 5 classes, and since there are hardly any ideal calm conditions in Hamilton, few occurrences were included in the first wind speed class (0-5 km/hr). The length of each wind speed class represents the corresponding average pollution concentration. At the end of each wind direction, values of five summary measures: a-total number of observations (hourly), b-annual average concentration, c-percent of observations, d-maximum hourly concentration and e-standard deviation are presented in a circle.

Overall, in each wind direction, the corresponding total length is directly proportional to the average pollution concentration for the total number of observations. In other words, the longer the length, the higher the average concentration

ONTARIO MINISTRY OF THE ENVIRONMENT - AIR RESOURCES BRANCH

TABULATION OF HOURLY POLLUTANT DATA BY WS/WD CLASSES

UNIT - 0.1 COMS/1000 FT
TIME PERIOD - JAN 79 TO DEC 79POLLUTANT - PARTICULATES - SOILING INDEX
STATION - NO 29008 NORTH PARK HAMILTON
WIND STATION NO 29026

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
- 5 NO. OBS	312		301		203		130		132		194		149		100		1521
AVG CON	6.6		6.4		6.2		6.6		7.7		10.8		8.9		9.7		7.6
PERCENT	4.1		3.9		2.6		1.7		1.7		2.5		1.9		1.3		19.8
MAX CON	28		24		26		21		22		33		26		30		33
STD DEV	5.4		5.0		5.9		5.4		5.1		5.6		4.8		6.3		5.6
6-11 NO. OBS	206		365		251		75		148		401		216		137		1799
AVG CON	4.8		4.1		3.9		6.0		9.7		12.0		8.4		7.9		7.3
PERCENT	2.7		4.8		3.3		1.0		1.9		5.2		2.8		1.8		23.5
MAX CON	24		23		17		28		25		36		25		30		36
STD DEV	4.6		3.2		2.9		5.2		5.6		5.5		5.0		5.8		5.6
12-17 NO. OBS	136		255		246		38		128		385		384		198		1770
AVG CON	3.2		3.0		3.4		4.6		10.7		12.4		7.1		7.1		7.1
PERCENT	1.8		3.3		3.2		0.5		1.7		5.0		5.0		2.6		23.1
MAX CON	20		28		16		18		27		32		24		22		32
STD DEV	3.5		3.2		3.0		3.4		5.6		5.4		4.9		5.1		5.8
18-23 NO. OBS	107		115		75		4		122		353		432		210		1418
AVG CON	2.6		1.6		3.7		3.3		10.3		11.8		7.1		6.4		7.5
PERCENT	1.4		1.5		1.0		0.1		1.6		4.6		5.6		2.7		18.5
MAX CON	14		8		22		6		31		24		24		19		31
STD DEV	2.6		1.7		3.4		1.9		6.8		4.6		4.8		3.9		5.5
24-29 NO. OBS	65		74		71		1		101		394		363		93		1162
AVG CON	3.8		1.7		1.8		0.0		10.2		12.7		6.7		5.2		8.1
PERCENT	0.8		1.0		0.9		0.0		1.3		5.1		4.7		1.2		15.1
MAX CON	32		9		7		28		28		32		18		13		32
STD DEV	5.5		1.8		1.8		6.9		6.9		5.1		3.8		3.0		5.9
TOTAL NO. OBS	826		1110		846		248		631		1727		1544		738		7670
AVG CON	4.9		4.1		4.1		6.1		9.7		12.1		7.4		7.2		7.6
PERCENT	10.8		14.5		11.0		3.2		8.2		22.5		20.1		9.6		100.0
MAX CON	32		28		26		28		31		36		26		30		36
STD DEV	4.9		4.0		4.0		5.1		6.0		5.3		4.7		5.1		5.7
CALM NO. OBS																	
AVG CON																	
PERCENT																	
MAX CON																	
STD DEV																	
GRAND MEAN																	7670
PERCENT MAXIMUM																	100.0
STD DEV																	36

TABLE 5

ONTARIO MINISTRY OF THE ENVIRONMENT - AIR RESOURCES BRANCH
TABULATION OF HOURLY POLLUTANT DATA BY WS/WD CLASSES

POLLUTANT - PARTICULATES - SOILING INDEX
STATION - NO 2900R NORTH PARK HAMILTON
WIND STATION NO 29026

UNIT - 0.1 CONHS/1000 FT
TIME PERIOD - JAN 80 TO DEC 80

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WIND SPEED IN KILOMETRES/HOUR				NNW	TOTAL
												WSW	W	WNW	NW		
- 5	NO. OBS	196	196	161	80	94	112	101	78	1020							
	AVG CON	7.8	5.3	4.9	6.3	10.9	11.1	8.6	9.6	7.6							
	PERCENT	2.3	2.4	1.9	1.0	1.1	1.3	1.2	0.9	12.2							
	MAX CON	43	33	23	21	30	26	34	36	43							
	STD DEV	5.8	4.3	4.0	4.9	6.5	5.2	5.5	6.2	5.7							
6-11	NO. OBS	247	274	219	77	114	430	378	165	1904							
	AVG CON	4.8	3.5	3.4	3.9	9.4	12.4	9.6	7.3	7.6							
	PERCENT	2.9	3.3	2.6	0.9	1.4	5.1	4.5	2.0	22.7							
	MAX CON	27	27	16	22	29	34	28	22	34							
	STD DEV	4.1	3.3	2.8	3.6	6.1	5.1	5.7	4.6	5.8							
12-17	NO. OBS	219	298	293	38	97	611	573	220	2349							
	AVG CON	3.7	2.3	2.6	3.2	10.0	11.8	8.9	6.7	7.3							
	PERCENT	2.6	3.6	3.5	0.5	1.2	7.3	6.8	2.6	28.0							
	MAX CON	16	14	14	17	22	27	32	20	32							
	STD DEV	2.8	2.4	2.4	2.8	4.9	4.6	5.5	4.6	5.6							
18-23	NO. OBS	185	122	149	9	66	442	522	261	1756							
	AVG CON	2.8	2.1	1.9	3.3	9.7	11.0	8.0	6.0	7.0							
	PERCENT	2.2	1.5	1.6	0.1	0.8	5.3	6.2	3.1	20.9							
	MAX CON	22	28	12	6	20	22	33	18	33							
	STD DEV	2.8	3.2	1.8	1.9	4.6	4.0	5.3	3.8	5.2							
24-99	NO. OBS	59	84	159	1	85	346	400	231	1365							
	AVG CON	3.0	1.5	1.2	4.0	9.9	11.0	6.4	4.9	6.5							
	PERCENT	0.7	1.0	1.9	0.0	1.0	4.1	4.8	2.8	16.3							
	MAX CON	35	12	9	4	19	21	23	27	35							
	STD DEV	4.9	1.9	1.4	4.4	4.4	3.9	4.5	3.9	5.2							
TOTAL	NO. OBS	906	976	981	205	456	1941	1974	955	1365							
	AVG CON	4.7	3.2	2.8	4.7	10.0	11.6	8.3	6.4	6.5							
	PERCENT	10.8	11.6	11.7	2.4	5.4	23.1	23.5	11.4	16.3							
	MAX CON	43	33	23	22	30	34	34	36	43							
	STD DEV	4.5	3.4	2.8	4.2	5.5	4.5	5.4	4.5	5.2							
CALM	NO. OBS																
	AVG CON																
	PERCENT																
	MAX CON																
	STD DEV																
GRAND MEAN 8394 PERCENT 7.2 MAXIMUM 100.0 STD DEV 43 5.5																	

TABLE 6

ONTARIO MINISTRY OF THE ENVIRONMENT - AIR RESOURCES BRANCH
 TABULATION OF HOURLY POLLUTANT DATA BY WS/WD CLASSES
 UNIT - 0.1 COHS/1000 FT
 TIME PERIOD - JAN 81 TO DEC 81
 WIND SPEED IN KILOMETRES/HOUR

WIND STATION NO 29026		WIND SPEED IN KILOMETRE PER HOUR																NNW	TOTAL
SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW				
- 5	NO. OBS	145		194		132		104		112		156		167		105		1155	
	AVG CON	7.2		5.6		5.9		7.7		9.7		9.6		8.8		10.0		7.9	
	PERCENT	2.3		2.4		1.6		1.3		1.4		1.9		2.1		1.3		14.4	
	MAX CON	29		25		28		22		27		28		26		29		29	
	STD DEV	4.6		4.7		5.0		5.1		6.1		5.4		5.3		6.1		5.5	
6-11	NO. OBS	279		366		313		115		142		498		431		190		2354	
	AVG CON	4.7		3.3		3.8		5.4		9.5		10.7		9.2		8.1		7.0	
	PERCENT	3.5		4.8		3.9		1.4		1.8		6.2		5.4		2.4		29.3	
	MAX CON	21		18		17		23		28		25		33		26		33	
	STD DEV	3.7		2.5		2.8		4.5		5.6		4.8		5.3		4.8		5.2	
12-17	NO. OBS	256		225		314		17		109		500		520		326		2267	
	AVG CON	3.7		2.2		2.9		4.7		8.9		11.6		8.8		6.8		7.1	
	PERCENT	3.2		2.8		3.9		0.2		1.4		6.2		6.5		4.1		28.2	
	MAX CON	21		14		25		9		40		31		41		22		41	
	STD DEV	3.0		2.3		2.7		3.1		6.0		4.5		6.1		4.5		5.6	
18-23	NO. OBS	123		110		85		1		59		336		400		252		1366	
	AVG CON	3.4		1.2		2.2		3.0		8.6		12.0		6.8		6.2		7.0	
	PERCENT	1.5		1.4		1.1		0.0		0.7		4.2		5.0		3.1		17.0	
	MAX CON	15		6		12		3		19		22		27		19		27	
	STD DEV	3.3		1.6		2.4		4.6		4.6		4.0		4.7		4.2		5.3	
24-99	NO. OBS	49		55		47		39		39		286		272		154		902	
	AVG CON	3.0		1.1		2.2		7.7		7.7		12.2		6.8		5.6		7.6	
	PERCENT	0.6		0.7		0.6		0.5		0.5		3.6		3.4		1.9		11.2	
	MAX CON	17		5		7		15		15		24		19		16		24	
	STD DEV	3.4		1.4		2.4		4.0		4.0		4.2		3.7		3.4		5.1	
TOTAL	NO. OBS	892		970		891		237		461		1776		1790		1027			
	AVG CON	4.6		3.2		3.6		6.4		9.2		11.3		8.2		7.0			
	PERCENT	11.1		12.1		11.1		2.9		5.7		22.1		22.3		12.8			
	MAX CON	29		25		28		23		40		31		41		29			
	STD DEV	3.9		3.2		3.3		4.8		5.6		4.6		5.3		4.7			
CALM	NO. OBS																	8044	
	AVG CON																	7.2	
	PERCENT																	100.0	
	MAX CON																	41	
	STD DEV																	5.4	
																		GRAND MEAN	8044
																		PERCENT	7.2
																		MAXIMUM	100.0
																		STD DEV	41
																			5.4

TABLE 7

ONTARIO MINISTRY OF THE ENVIRONMENT - AIR RESOURCES BRANCH
 TABULATION OF HOURLY POLLUTANT DATA BY WS/WD CLASSES
 UNIT - 0.1 CONCS/1000 FT
 TIME PERIOD - JAN 79 TO DEC 79
 WIND SPEED IN KILOMETRES/HOUR

POLLUTANT - PARTICULATES - SOILING INDEX
 STATION - NO 29025 HAMILTON
 WIND STATION NO 29026

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
- 5 NO. OBS	317		308		208		135		143		202		151		101		1565
AVG CON	8.1		12.1		11.1		10.7		9.0		7.2		5.8		8.3		9.3
PERCENT	4.0		3.9		2.6		1.7		1.8		2.5		1.9		1.3		19.6
MAX CON	33		43		41		40		37		38		28		35		43
STD DEV	5.5		7.3		6.6		7.5		6.7		5.7		5.1		6.8		6.7
6-11 NO. OBS	217		379		256		82		151		418		222		142		1867
AVG CON	6.4		11.8		9.9		8.7		5.6		4.8		4.3		4.0		7.2
PERCENT	2.7		4.7		3.2		1.0		1.9		5.2		2.8		1.8		23.4
MAX CON	39		35		35		43		30		23		23		16		43
STD DEV	6.1		6.3		6.3		6.9		4.2		3.5		2.9		2.8		5.9
12-17 NO. OBS	143		259		257		38		139		406		398		205		1845
AVG CON	4.3		10.4		8.4		7.6		4.3		4.3		3.5		3.2		5.5
PERCENT	1.8		3.2		3.2		0.5		1.7		5.1		5.0		2.6		23.1
MAX CON	21		30		32		18		15		25		20		11		32
STD DEV	4.2		5.0		5.9		3.7		2.6		3.3		2.4		2.1		4.6
18-23 NO. OBS	114		128		90		4		130		364		442		220		1492
AVG CON	2.4		10.7		8.7		5.3		4.5		4.1		3.2		3.2		4.4
PERCENT	1.4		1.6		1.1		0.1		1.6		4.6		5.5		2.8		18.7
MAX CON	17		23		24		8		11		17		21		10		24
STD DEV	2.9		4.7		4.6		2.2		2.3		2.5		2.2		2.0		3.6
24-99 NO. OBS	66		87		73		1		107		409		368		101		1212
AVG CON	2.0		10.0		8.8		3.0		4.4		4.0		3.2		2.9		4.3
PERCENT	0.8		1.1		0.9		0.0		1.3		5.1		4.6		1.3		15.2
MAX CON	8		20		29		3		11		11		14		9		29
STD DEV	1.9		4.9		4.4		2.1		2.0		2.0		1.7		1.7		3.2
TOTAL	857		1151		884		260		670		1799		1581		769		7981
AVG CON	5.8		11.3		9.5		9.5		5.7		4.6		3.6		4.0		6.3
PERCENT	10.7		14.5		11.1		3.3		8.4		22.5		19.8		9.6		100.0
MAX CON	39		43		41		43		37		38		28		35		43
STD DEV	5.5		6.1		6.0		6.9		4.5		3.5		2.8		3.6		5.4
CALM	NO. OBS																
AVG CON																	
PERCENT																	
MAX CON																	
STD DEV																	

GRAND
 MEAN
 PERCENT
 MAXIMUM
 STD DEV

TABLE 8

ONTARIO MINISTRY OF THE ENVIRONMENT - AIR RESOURCES BRANCH

TABULATION OF HOURLY POLLUTANT DATA BY WS/WD CLASSES

 POLLUTANT - PARTICULATES - SOLLING INDEX
 STATION - NO 29025 HAMILTON/SHAWFORD
 WIND STATION NO 29026

 UNIT - 0.1 COHS/1000 FT
 TIME PERIOD - JAN 80 TO DEC 80

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
- 5 NO. OBS	196		200		160		80		96		113		101		75		1021
AVG CON	8.1	9.6	9.6	8.7	8.7		8.3		8.5		8.6		6.9		7.7		8.4
PERCENT	2.3	2.4	2.4	1.9	1.9		0.9		1.1		1.3		1.2		0.9		12.1
MAX CON	26	33	33	25	25		26		35		21		21		22		35
STD DEV	5.0		5.8		4.3		4.7		5.1		5.0		4.4		4.5		5.0
6-11 NO. OBS	246		212		213		76		116		437		377		165		1902
AVG CON	4.8		9.2		7.8		6.2		6.3		5.4		4.5		4.7		6.0
PERCENT	2.9		3.2		2.5		0.9		1.4		5.2		4.4		1.9		22.4
MAX CON	21		26		23		25		21		22		16		15		26
STD DEV	4.0		4.9		4.4		4.0		3.4		2.9		2.6		2.7		3.9
12-17 NO. OBS	218		305		295		38		98		628		579		219		2380
AVG CON	3.4		9.5		7.0		5.0		5.6		4.7		3.8		3.7		5.2
PERCENT	2.6		3.6		3.5		0.4		1.2		7.4		6.8		2.6		28.1
MAX CON	19		28		29		15		24		16		13		11		29
STD DEV	3.1		5.2		3.8		3.3		3.1		2.3		2.1		2.1		3.7
18-23 NO. OBS	186		120		152		9		69		464		528		261		1789
AVG CON	2.6		10.6		7.8		5.3		5.3		4.3		3.3		3.0		4.4
PERCENT	2.2		1.4		1.8		0.1		0.8		5.5		6.2		3.1		21.1
MAX CON	19		28		19		10		13		12		11		13		28
STD DEV	2.9		5.1		3.5		2.6		2.5		2.2		2.0		2.1		3.4
24-99 NO. OBS	59		86		159		1		85		352		406		233		1381
AVG CON	1.8		9.6		6.8		8.0		4.8		4.5		2.7		2.7		4.2
PERCENT	0.7		1.0		1.9		0.0		1.0		4.2		4.8		2.7		16.3
MAX CON	9		21		22		8		10		12		9		22		22
STD DEV	1.9		3.7		2.9		2.6		2.1		2.1		1.7		2.3		3.0
TOTAL NO. OBS	905		983		979		204		464		1994		1991		953		8473
AVG CON	4.5		9.6		7.5		6.8		6.2		4.9		3.7		3.8		5.4
PERCENT	10.7		11.6		11.6		2.4		5.5		23.5		23.5		11.2		100.0
MAX CON	26		33		29		26		35		22		21		22		35
STD DEV	4.3		5.1		3.9		4.3		3.7		2.8		2.5		2.9		4.0
CALM NO. OBS																	
AVG CON																	
PERCENT																	
MAX CON																	
STD DEV																	

 GRAND 8473
 MEAN 5.4
 PERCENT 100.0
 MAXIMUM 35
 STD DEV 4.0

TABLE 9

ONTARIO MINISTRY OF THE ENVIRONMENT - AIR RESOURCES BRANCH

TABULATION OF HOURLY POLLUTANT DATA BY WS/WD CLASSES

UNIT - 0.1 COHS/1000 FT

TIME PERIOD - JAN 81 TO DEC 81

WIND SPEED IN KILOMETRES/HOUR

POLLUTANT - PARTICULATES - SOILING INDEX
 STATION - NO 29025 HARTON / SAUPELO
 WIND STATION NO 29026

HAMILTON

SPEED	N	NNE	NE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
- 5 NO. OBS	185		204	128		102		114		154		165		109		1161
AVG CON	8.7		9.4	9.2		9.0		9.0		8.4		7.4		8.4		8.7
PERCENT	5.3		2.5	1.6		1.3		1.4		1.9		2.0		1.3		14.2
MAX CON	29		30	32		22		25		28		23		24		32
STD DEV	5.5		5.4	4.7		4.7		5.3		4.8		4.4		5.2		5.1
6-11 NO. OBS	284		390	320		116		143		499		433		190		2375
AVG CON	5.2		9.2	9.3		6.9		7.4		5.6		5.1		4.4		6.6
PERCENT	3.5		4.8	3.9		1.4		1.8		6.1		5.3		2.3		29.1
MAX CON	27		29	37		19		27		23		40		13		40
STD DEV	4.0		5.0	5.8		3.6		5.1		3.0		3.5		2.5		4.6
12-17 NO. OBS	262		225	325		17		108		499		532		323		2291
AVG CON	3.1		8.2	8.0		6.5		5.0		5.2		4.0		3.4		5.1
PERCENT	3.2		2.8	4.0		0.2		1.3		6.1		6.5		4.0		28.1
MAX CON	18		24	29		13		24		15		43		10		43
STD DEV	2.6		4.4	5.0		3.9		3.0		2.4		2.9		2.0		3.7
18-23 NO. OBS	140		110	86		1		59		338		410		259		1403
AVG CON	2.4		6.5	7.2		5.0		4.8		4.9		3.5		3.1		4.2
PERCENT	1.7		1.3	1.1		0.0		0.7		4.1		5.0		3.2		17.2
MAX CON	15		15	19		5		12		15		12		11		19
STD DEV	2.4		3.1	3.9				2.6		2.1		2.1		2.1		2.7
24-99 NO. OBS	52		55	47				39		293		281		158		925
AVG CON	2.0		8.0	6.7				4.2		4.5		3.4		2.8		4.1
PERCENT	0.6		0.7	0.6				0.5		3.6		3.4		1.9		11.3
MAX CON	9		16	16				10		11		14		8		16
STD DEV	1.8		3.5	3.5				2.5		1.9		2.1		1.8		2.6
TOTAL	923		984	906		236		463		1783		1821		1039		8155
AVG CON	4.7		8.6	8.5		7.8		6.6		5.4		4.4		3.9		5.8
PERCENT	11.3		12.1	11.1		2.9		5.7		21.9		22.3		12.7		100.0
MAX CON	29		30	37		22		27		28		43		24		43
STD DEV	4.4		4.8	5.2		4.2		4.6		2.9		3.2		3.1		4.2
CALM	NO. OBS															
AVG CON																
PERCENT																
MAX CON																
STD DEV																
GRAND																
MEAN																8155
PERCENT																5.8
MAXIMUM																100.0
STD DEV																4.3

TABLE 10

ONTARIO MINISTRY OF THE ENVIRONMENT - AIR RESOURCES BRANCH
 TABLE 11
 POLLUTANT - SULPHUR DIOXIDE
 STATION - NO. 29008 NORTH PARK HAMILTON
 WIND STATION NO. 29026

POLLUTANT - SULPHUR DIOXIDE																GR
STATION - NO 29008 NORTH PARK HAMILTON																ME
WIND STATION NO 29026																PER
UNIT - 0.01 PARTS/MILLION																MAX
TIME PERIOD - JAN 79 TO DEC 79																STD
WIND SPEED IN KILOMETRES/HOUR																
SPEED	N	NNW	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	
- 5	NO. OBS	318	311		204		128		142		195		149		99	
	AVG CON	0.2	0.3		0.3		0.4		0.7		1.2		0.3		0.3	
	PERCENT	4.0	3.9		2.6		1.6		1.8		2.5		1.9		1.3	
	MAX CON	7	11		4		10		5		10		5		9	
	STD DEV	0.8	0.8		0.6		1.0		1.2		1.7		0.7		1.0	
6-11	NO. OBS	219	376		254		75		150		416		221		141	
	AVG CON	0.3	0.3		0.4		0.5		1.2		2.3		0.8		0.1	
	PERCENT	2.4	4.6		3.2		0.9		1.9		5.3		2.4		1.4	
	MAX CON	6	5		3		4		10		10		5		3	
	STD DEV	0.8	0.7		0.6		0.8		1.7		2.2		1.3		0.5	
12-17	NO. OBS	142	260		255		37		140		405		399		204	
	AVG CON	0.3	0.2		0.3		0.9		1.5		3.2		0.9		0.2	
	PERCENT	1.8	3.3		3.2		0.5		1.8		5.1		5.0		2.6	
	MAX CON	3	2		7		5		8		13		7		3	
	STD DEV	0.6	0.5		0.8		1.2		1.7		2.3		1.5		0.5	
18-23	NO. OBS	114	124		89		4		124		360		433		221	
	AVG CON	0.4	0.2		0.5		0.5		1.3		3.7		1.3		0.2	
	PERCENT	1.4	1.6		1.1		0.1		1.6		4.5		5.5		2.8	
	MAX CON	2	3		3		1		8		10		10		3	
	STD DEV	0.6	0.5		0.8		0.6		1.5		2.1		1.8		0.4	
24-99	NO. OBS	68	86		71		1		101		404		366		101	
	AVG CON	0.2	0.7		0.4				1.5		4.1		1.6		0.2	
	PERCENT	0.9	1.1		0.9		0.0		1.3		5.1		4.6		1.3	
	MAX CON	1	3		4				9		14		7		4	
	STD DEV	0.4	0.7		0.7				1.5		2.4		1.7		0.7	
TOTAL	NO. OBS	861	1157		873		245		657		1780		1568		766	
	AVG CON	0.3	0.3		0.4		0.5		1.2		3.1		1.1		0.2	
	PERCENT	10.9	14.6		11.0		3.1		8.3		22.5		19.8		9.7	
	MAX CON	7	11		7		10		10		14		10		9	
	STD DEV	0.7	0.7		0.7		1.0		1.6		2.4		1.6		0.6	
CALM	NO. OBS															
	AVG CON															
	PERCENT															
	MAX CON															
	STD DEV															

TABLE 11

ONTARIO MINISTRY OF THE ENVIRONMENT - AIR RESOURCES BRANCH
TABULATION OF HOURLY POLLUTANT DATA BY WS/WD CLASSES

POLLUTANT - SULPHUR DIOXIDE
STATION - NO 29008 NORTH PARK HAMILTON
WIND STATION NO 29026

UNIT - 0.01 PARTS/MILLION
TIME PERIOD - JAN 80 TO DEC 80

WIND SPEED IN KILOMETRES/HOUR

SPEED	N	NNE	NE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
- 5 NO. OBS	191		192	155		74		96		109		98		76		991
AVG CON	0.8		0.6	0.6		0.6		1.3		1.9		0.7		0.7		0.9
PERCENT	2.3		2.3	1.9		0.9		1.2		1.3		1.2		0.9		12.1
MAX CON	6		4	3		3		9		10		8		5		10
STD DEV	1.0		0.9	0.9		0.8		1.7		2.3		1.2		0.9		1.3
6-11 NO. OBS	241		254	216		75		117		429		359		159		1850
AVG CON	0.7		0.5	0.7		0.6		1.4		3.0		1.1		0.7		1.3
PERCENT	2.9		3.1	2.6		0.9		1.4		5.2		4.4		1.9		22.5
MAX CON	7		3	4		3		10		13		9		3		13
STD DEV	1.1		0.7	0.9		0.9		1.7		2.7		1.6		0.8		1.9
12-17 NO. OBS	211		271	278		37		96		613		553		214		2279
AVG CON	0.5		0.5	0.6		0.5		1.7		3.2		1.5		0.5		1.5
PERCENT	2.6		3.4	3.4		0.5		1.2		7.5		6.7		2.6		27.8
MAX CON	3		4	4		3		6		12		11		9		12
STD DEV	0.8		0.8	0.8		0.8		1.4		2.5		2.0		1.0		2.1
18-23 NO. OBS	182		115	146		9		69		456		517		260		1754
AVG CON	0.4		0.6	0.6		0.4		1.7		3.2		1.3		0.3		1.5
PERCENT	2.2		1.4	1.8		0.1		0.8		5.6		6.3		3.2		21.4
MAX CON	3		3	6		3		10		12		8		3		12
STD DEV	0.7		0.8	0.9		1.0		1.8		2.0		1.6		0.6		1.8
24-99 NO. OBS	60		74	156		1		80		340		396		231		1338
AVG CON	0.6		0.2	0.2		1.0		1.7		3.3		1.1		0.4		1.4
PERCENT	0.7		0.9	1.9		0.0		1.0		4.1		4.8		2.8		16.3
MAX CON	3		2	2		1		7		10		6		7		10
STD DEV	0.9		0.5	0.5		1.4		1.4		2.2		1.4		0.7		1.9
TOTAL NO. OBS	885		912	951		196		458		1947		1923		940		8212
AVG CON	0.6		0.5	0.6		0.6		1.5		3.1		1.2		0.5		1.4
PERCENT	10.8		11.1	11.6		2.4		5.6		23.7		23.4		11.4		100.0
MAX CON	7		4	6		3		10		13		11		9		13
STD DEV	0.9		0.6	0.8		0.9		1.6		2.4		1.7		0.8		1.9
CALM	NO. OBS															
AVG CON																
PERCENT																
MAX CON																
STD DEV																
GRAND MEAN																8212
PERCENT MAXIMUM																100.0
STD DEV																1.9

TABLE 12

ONTARIO MINISTRY OF THE ENVIRONMENT - AIR RESOURCES BRANCH
TABULATION OF HOURLY POLLUTANT DATA BY WS/WD CLASSES

POLLUTANT - SULPHUR DIOXIDE

STATION - NO 29008 NORTH PARK HAMILTON

WIND STATION NO 29026

UNIT - 0.01 PARTS/MILLION
TIME PERIOD - JAN 81 TO DEC 81

WIND SPEED IN KILOMETRES/HOUR

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
- 5 NO. OBS	186	194	194	128	100	104	143	144	101	144	101	144	101	144	101	144	1100
AVG CON	0.7	0.6	0.6	0.9	0.9	1.5	1.1	0.7	1.1	0.7	1.1	0.7	1.1	0.7	1.1	0.9	0.9
PERCENT	2.4	2.5	2.5	1.6	1.3	1.3	1.9	1.8	1.3	1.8	1.3	1.8	1.3	1.8	1.3	14.0	14.0
MAX CON	3	5	5	4	4	7	8	5	3	7	3	5	3	7	3	8	8
STD DEV	0.8	0.8	0.8	0.9	1.1	1.4	1.2	0.9	1.0	0.9	1.0	0.9	1.0	0.9	1.0	1.0	1.0
6-11 NO. OBS	274	372	372	303	108	139	472	395	186	395	186	395	186	395	186	2249	2249
AVG CON	0.6	0.6	0.6	0.8	0.8	1.6	2.3	1.0	0.9	1.0	0.9	1.0	0.9	1.0	0.9	1.2	1.2
PERCENT	3.5	4.7	4.7	3.9	1.4	1.8	6.0	5.0	2.4	5.0	2.4	5.0	2.4	5.0	2.4	28.7	28.7
MAX CON	5	9	9	5	3	9	11	7	4	7	4	7	4	7	4	11	11
STD DEV	0.9	0.9	0.9	0.9	0.8	1.4	2.2	1.1	1.0	1.1	1.0	1.1	1.0	1.1	1.0	1.5	1.5
12-17 NO. OBS	263	223	223	294	15	105	489	521	320	521	320	521	320	521	320	2230	2230
AVG CON	0.6	0.7	0.7	0.8	1.2	2.0	3.6	1.5	0.6	1.5	0.6	1.5	0.6	1.5	0.6	1.6	1.6
PERCENT	3.4	2.8	2.8	3.8	0.2	1.3	6.2	6.7	4.1	6.7	4.1	6.7	4.1	6.7	4.1	28.5	28.5
MAX CON	4	11	11	8	3	8	10	11	5	11	5	11	5	11	5	11	11
STD DEV	0.8	1.2	1.2	0.9	0.9	1.8	2.4	1.8	0.8	1.8	0.8	1.8	0.8	1.8	0.8	2.0	2.0
18-23 NO. OBS	141	110	110	84	1	57	332	385	267	385	267	385	267	385	267	1377	1377
AVG CON	0.7	0.6	0.6	0.7	0.0	2.5	3.8	1.1	0.4	1.1	0.4	1.1	0.4	1.1	0.4	1.6	1.6
PERCENT	1.8	1.4	1.4	1.1	0.0	0.7	4.2	4.9	3.4	4.9	3.4	4.9	3.4	4.9	3.4	17.6	17.6
MAX CON	3	11	11	5	0	9	12	8	4	8	4	8	4	8	4	12	12
STD DEV	0.9	1.3	1.3	1.0	0.9	2.4	2.3	1.4	0.6	1.4	0.6	1.4	0.6	1.4	0.6	2.1	2.1
24-99 NO. OBS	53	55	55	46	35	35	273	258	156	258	156	258	156	258	156	874	874
AVG CON	0.5	0.4	0.4	0.7	2.4	2.4	4.0	1.2	0.6	1.2	0.6	1.2	0.6	1.2	0.6	1.9	1.9
PERCENT	0.7	0.7	0.7	0.6	0.4	0.4	3.5	3.3	2.0	3.3	2.0	3.3	2.0	3.3	2.0	11.2	11.2
MAX CON	2	8	8	4	8	8	11	6	4	6	4	6	4	6	4	11	11
STD DEV	0.5	1.1	1.1	0.9	2.0	2.0	2.1	1.5	0.7	1.5	0.7	1.5	0.7	1.5	0.7	2.1	2.1
TOTAL NO. OBS	917	954	954	855	224	440	1709	1703	1030	1703	1030	1703	1030	1703	1030	7832	7832
AVG CON	0.6	0.6	0.6	0.8	0.9	1.8	3.1	1.2	0.7	1.2	0.7	1.2	0.7	1.2	0.7	1.4	1.4
PERCENT	11.7	12.2	12.2	10.9	2.9	5.6	21.8	21.7	13.2	21.7	13.2	21.7	13.2	21.7	13.2	100.0	100.0
MAX CON	5	11	11	8	4	9	12	11	5	11	5	11	5	11	5	12	12
STD DEV	0.8	1.0	1.0	0.9	0.9	1.7	2.4	1.5	0.8	1.5	0.8	1.5	0.7	1.5	0.7	1.8	1.8
CALM NO. OBS																	
AVG CON																	
PERCENT																	
MAX CON																	
STD DEV																	
GRAND MEAN																	7832
PERCENT MAXIMUM																	100.0
STD DEV																	1.8

TABLE 13

ONTARIO MINISTRY OF THE ENVIRONMENT - AIR RESOURCES BRANCH
TABULATION OF HOURLY POLLUTANT DATA BY WS/WD CLASSES

POLLUTANT - SULPHUR DIOXIDE

STATION - NO 29025 HARTONY, HAMILTON

WIND STATION NO 29026

SANFORD

UNIT - 0.01 PARTS/MILLION
TIME PERIOD - JAN 79 TO DEC 79
WIND SPEED IN KILOMETRES/HOUR

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
- 5	NO. OBS	320	313	207	135	144	202	152	100	1573							
	AVG CON	1.5	2.7	2.1	1.9	1.5	1.0	0.9	1.4	1.7							
	PERCENT	4.0	3.9	2.6	1.7	1.8	2.5	1.9	1.2	19.6							
	MAX CON	8	15	10	13	7	5	6	10	15							
	STD DEV	1.5	2.5	1.9	1.7	1.3	0.9	1.0	1.9	1.8							
6-11	NO. OBS	218	378	256	81	152	418	223	141	1867							
	AVG CON	2.2	4.2	2.9	1.9	1.4	0.9	0.8	0.8	2.0							
	PERCENT	2.7	4.7	3.2	1.9	1.9	5.2	2.8	1.8	23.3							
	MAX CON	11	20	13	15	12	12	7	12	20							
	STD DEV	2.6	3.1	2.5	2.1	2.0	1.1	0.9	1.3	2.5							
12-17	NO. OBS	143	263	263	36	140	408	400	204	1857							
	AVG CON	1.6	5.3	3.1	2.4	1.2	0.9	0.7	0.7	1.9							
	PERCENT	1.8	3.3	3.3	0.4	1.7	5.1	5.0	2.5	23.2							
	MAX CON	11	25	14	8	10	11	4	5	25							
	STD DEV	2.4	3.3	2.6	2.1	1.4	1.2	0.8	0.8	2.5							
18-23	NO. OBS	114	127	92	4	129	367	442	224	1499							
	AVG CON	1.0	5.9	3.3	1.3	1.4	1.0	0.7	0.6	1.5							
	PERCENT	1.4	1.6	1.1	0.0	1.6	4.6	5.5	2.8	18.7							
	MAX CON	11	15	11	2	16	11	4	3	16							
	STD DEV	1.9	3.3	2.2	0.5	1.7	1.1	0.7	0.7	2.1							
24-99	NO. OBS	68	87	72	1	106	410	372	101	1217							
	AVG CON	0.8	5.2	2.8	2.0	1.3	1.4	0.7	0.7	1.5							
	PERCENT	0.8	1.1	0.9	0.0	1.3	5.1	4.6	1.3	15.2							
	MAX CON	4	16	8	2	12	13	6	2	16							
	STD DEV	0.9	3.3	1.6	1.3	1.3	1.4	0.8	0.7	1.8							
TOTAL	NO. OBS	863	1168	890	257	671	1805	1599	770								
	AVG CON	1.6	4.3	2.8	1.9	1.4	1.1	0.7	0.8								
	PERCENT	10.8	14.6	11.1	3.2	8.4	22.5	19.8	9.6								
	MAX CON	11	25	14	15	16	13	7	12								
	STD DEV	2.1	3.2	2.4	1.9	1.6	1.2	0.8	1.1								
CALM	NO. OBS																
	AVG CON																
	PERCENT																
	MAX CON																
	STD DEV																
	GRAND MEAN																8013
	PERCENT																1.7
	MAXIMUM																100.0
	STD DEV																25
																	2.2

TABLE 14

ONTARIO MINISTRY OF THE ENVIRONMENT - AIR RESOURCES BRANCH

TABULATION OF HOURLY POLLUTANT DATA BY WS/WD CLASSES

POLLUTANT - SULPHUR DIOXIDE

STATION - NO 29025 BARTON / *SANFORD* *WINDMILLION*

WIND STATION NO 29026

UNIT - 0.01 PARTS/MILLION
TIME PERIOD - JAN 80 TO DEC 80
WIND SPEED IN KILOMETRES/HOUR

SPEED	N	NNE	NE	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
- 5 NO. OBS	196		201	161	80		99		111		102		77		1027
AVG CON	1.4		1.7	1.6	1.3		1.2		1.4		1.2		1.1		1.4
PERCENT	2.3		2.4	1.9	0.9		1.2		1.3		1.2		0.9		12.0
MAX CON	12		14	5	4		5		5		6		5		14
STD DEV	1.3		1.7	1.2	0.9		1.0		1.3		1.2		1.2		1.3
6-11 NO. OBS	248		275	216	76		116		436		382		165		1914
AVG CON	1.3		3.0	2.1	1.2		1.2		0.8		0.7		1.1		1.4
PERCENT	2.9		3.2	2.5	0.9		1.4		5.1		4.5		1.9		22.4
MAX CON	9		11	9	6		5		5		5		5		11
STD DEV	1.3		2.3	1.7	1.1		1.1		0.9		0.8		1.1		1.6
12-17 NO. OBS	222		303	296	38		99		612		582		223		2395
AVG CON	1.1		3.8	2.4	1.0		1.3		0.9		0.7		0.8		1.4
PERCENT	2.6		3.6	3.5	0.4		1.2		7.4		6.8		2.6		28.1
MAX CON	16		12	12	4		9		13		4		5		16
STD DEV	1.6		2.5	1.9	0.9		1.5		1.1		0.8		0.8		1.8
18-23 NO. OBS	187		122	149	9		70		468		532		264		1801
AVG CON	0.8		4.6	2.6	2.1		1.4		0.7		0.5		0.7		1.1
PERCENT	2.2		1.4	1.7	0.1		0.8		5.5		6.2		3.1		21.1
MAX CON	9		8	7	4		6		4		3		4		9
STD DEV	1.1		2.0	1.7	1.3		1.3		0.8		0.7		0.7		1.5
24-99 NO. OBS	60		86	161	1		86		357		408		234		1395
AVG CON	0.7		4.7	2.4	2.0		1.9		1.0		0.4		0.5		1.2
PERCENT	0.7		1.0	1.9	0.0		1.0		4.2		4.8		2.7		16.4
MAX CON	2		10	6	2		11		7		2		3		11
STD DEV	0.7		1.8	1.3	1.3		2.1		1.1		0.5		0.6		1.5
TOTAL NO. OBS	913		987	985	204		470		2004		2006		963		
AVG CON	1.1		3.3	2.2	1.2		1.4		0.9		0.6		0.8		
PERCENT	10.7		11.6	11.5	2.4		5.5		23.5		23.5		11.3		
MAX CON	16		14	12	6		11		13		6		5		
STD DEV	1.4		2.4	1.6	1.0		1.5		1.0		0.8		0.9		
CALM NO. OBS															8532
AVG CON															1.3
PERCENT															100.0
MAX CON															16
STD DEV															1.6

GRAND
MEAN
PERCENT
MAXIMUM
STD DEV

TABLE 15

ONTARIO MINISTRY OF THE ENVIRONMENT - AIR RESOURCES BRANCH
TABULATION OF HOURLY POLLUTANT DATA BY WS/WD CLASSES

POLLUTANT - SULPHUR DIOXIDE
STATION - NO 29025 BARTON
WIND STATION NO 29026

HAMILTON
JANUARY

UNIT - 0.01 PARTS/MILLION
TIME PERIOD - JAN 81 TO DEC 81
WIND SPEED IN KILOMETRES/HOUR

SPEED	N	NINE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
- 5	NO. OBS	191	206	133	105	113	157	165	108	1178							
	AVG CON	1.0	1.5	1.4	1.3	1.4	0.9	0.8	1.2	1.2							
	PERCENT	2.3	2.5	1.6	1.3	1.4	1.9	2.0	1.3	14.2							
	MAX CON	10	7	7	7	6	6	7	6	10							
	STD DEV	1.3	1.3	1.3	1.4	1.4	1.2	1.2	1.2	1.3							
6-11	NO. OBS	285	397	324	117	145	507	444	187	2406							
	AVG CON	0.8	2.4	2.1	1.2	1.2	0.7	0.5	0.8	1.2							
	PERCENT	3.4	4.8	3.9	1.4	1.7	6.1	5.3	2.3	29.0							
	MAX CON	7	14	9	5	7	7	4	5	14							
	STD DEV	1.0	2.1	1.9	1.2	1.5	1.0	0.7	1.0	1.6							
12-17	NO. OBS	269	227	325	17	109	507	554	337	2345							
	AVG CON	0.5	2.9	2.3	1.2	1.2	0.8	0.4	0.5	1.0							
	PERCENT	3.2	2.7	3.9	0.2	1.3	6.1	6.7	4.1	28.2							
	MAX CON	5	11	12	3	8	7	4	7	12							
	STD DEV	0.8	2.1	2.2	1.0	1.5	1.2	0.6	0.8	1.6							
18-23	NO. OBS	141	110	88	1	59	338	421	285	1443							
	AVG CON	0.3	2.5	1.9	1.0	1.4	0.8	0.4	0.4	0.8							
	PERCENT	1.7	1.3	1.1	0.0	0.7	4.1	5.1	3.4	17.4							
	MAX CON	3	7	7	1	5	7	8	3	8							
	STD DEV	0.6	1.7	1.6	1.4	1.4	1.1	0.7	0.6	1.2							
24-99	NO. OBS	53	55	46	39	295	161	286	161	935							
	AVG CON	0.2	2.8	2.2	1.4	1.0	0.4	0.5	0.4	0.9							
	PERCENT	0.6	0.7	0.6	0.5	3.6	1.9	3.4	1.9	11.3							
	MAX CON	2	6	6	5	6	3	2	3	6							
	STD DEV	0.5	1.5	1.4	1.3	0.9	0.6	0.5	0.6	1.1							
TOTAL	NO. OBS	939	995	916	240	465	1804	1870	1078	8307							
	AVG CON	0.6	2.3	2.0	1.2	1.3	0.8	0.5	0.6	1.0							
	PERCENT	11.3	12.0	11.0	2.9	5.6	21.7	22.5	13.0	100.0							
	MAX CON	10	14	12	7	8	7	8	7	14							
	STD DEV	1.0	2.0	1.9	1.3	1.5	1.1	0.7	0.8	1.4							
CALM	NO. OBS																
	AVG CON																
	PERCENT																
	MAX CON																
	STD DEV																

TABLE 16

- a: Total No. of observations (hourly)
- b: Annual average concentration
- c: Percent
- d: Maximum hourly concentration
- e: Standard deviation

0.1 .5 1.0 1.5 2.0 2.5 COHs / 1000ft Avg. Con

0-5 6-11 12-17 18-23 24- km/hr. Wind Speed

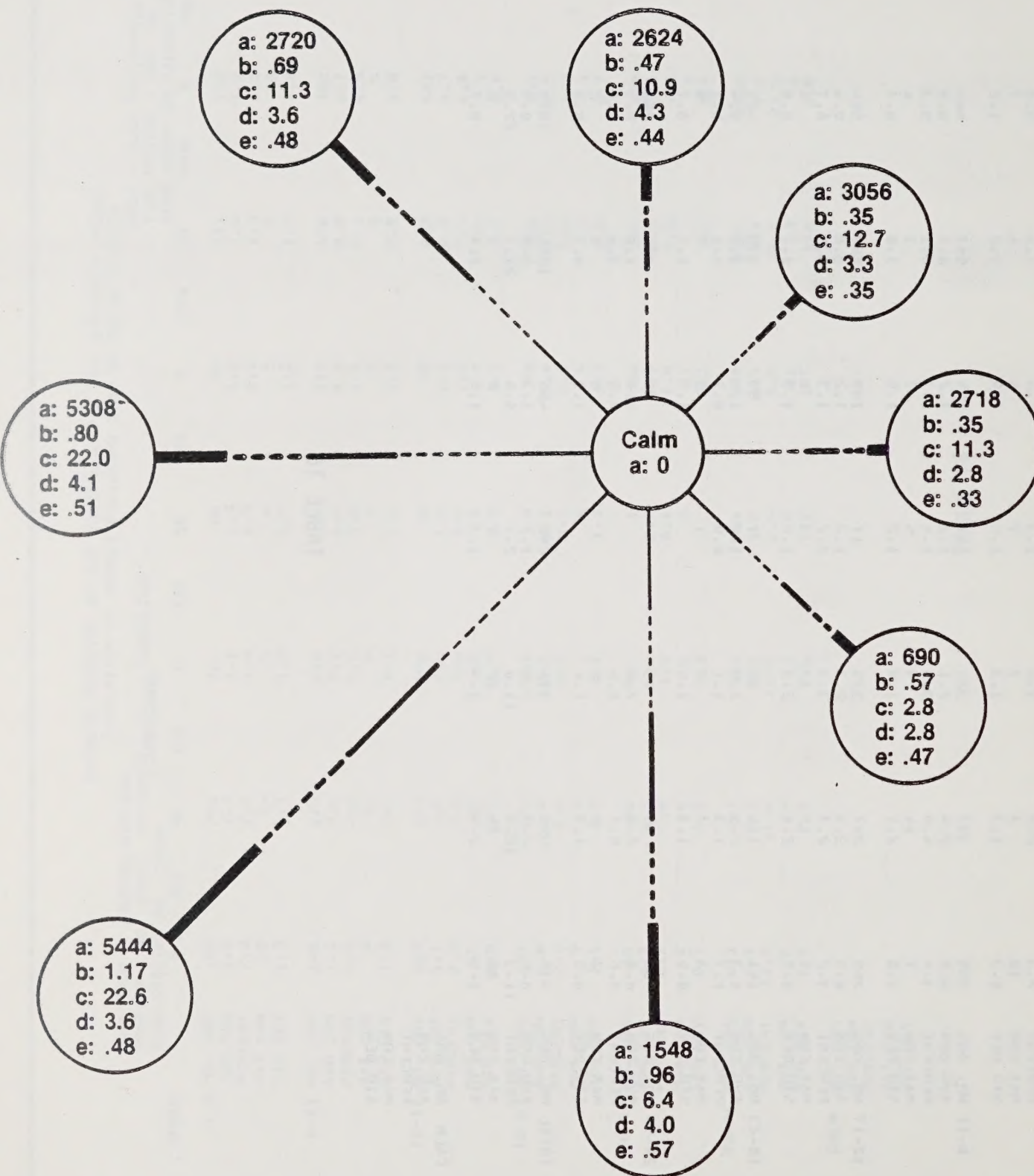


FIGURE 12 - Soiling index pollution rose, based on hourly measurements, for North Park Station, Hamilton, Ontario PERIOD: 1979-81

a: Total No. of observations (hourly)
b: Annual average concentration
c: Percent
d: Maximum hourly concentration
e: Standard deviation

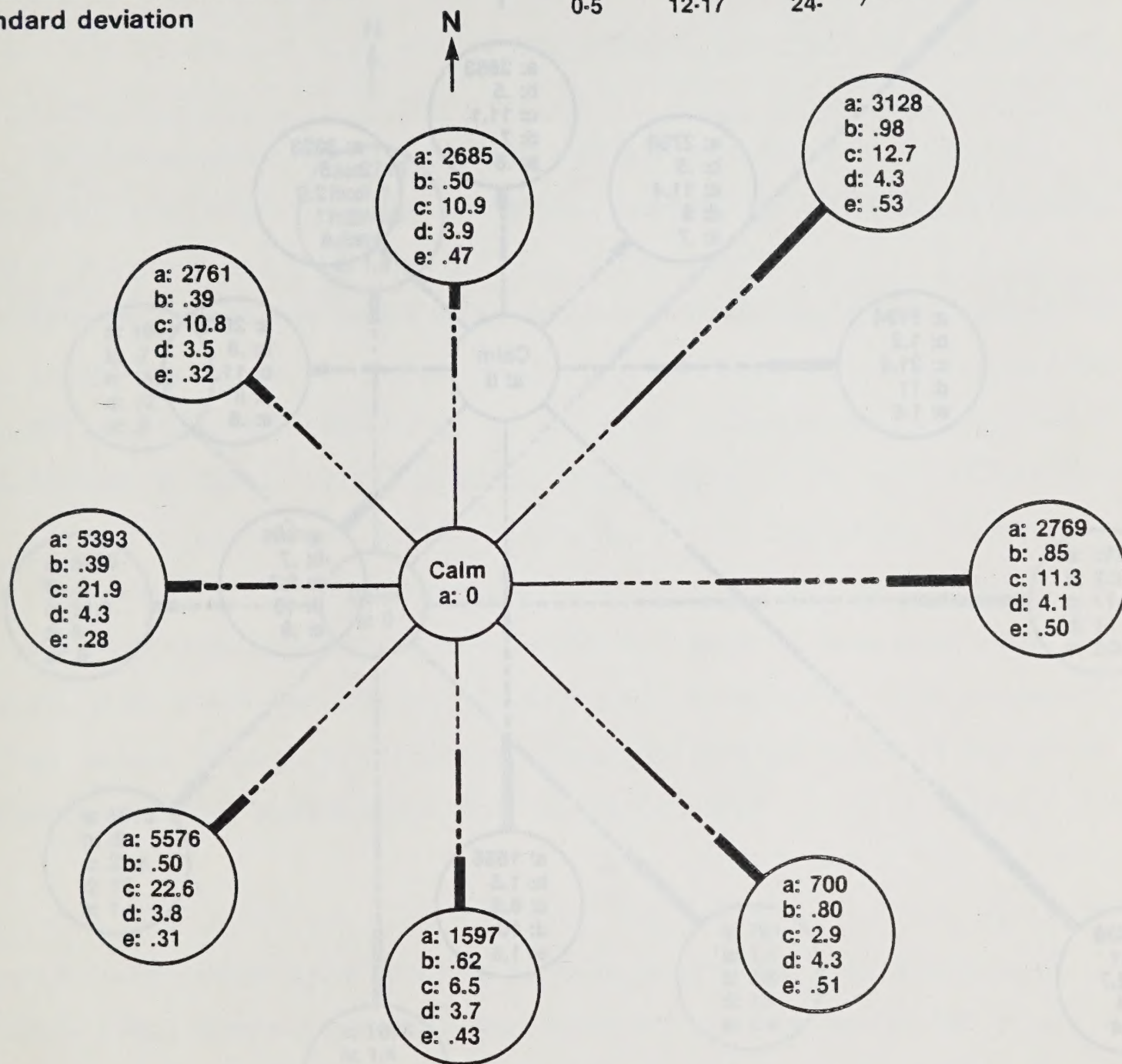
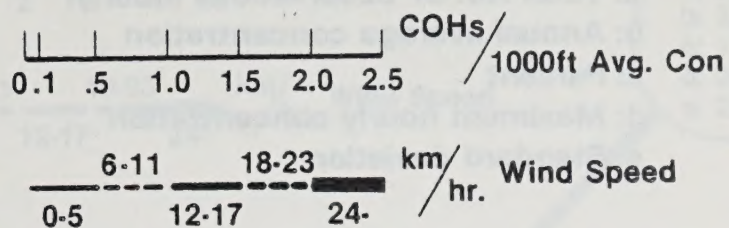


FIGURE 13 - Soiling index pollution rose, based on hourly measurements, for Barton/Sanford Station, Hamilton, Ontario PERIOD: 1979-81

a: Total No. of observations (hourly)
b: Annual average concentration
c: Percent
d: Maximum hourly concentration
e: Standard deviation

0 1 2 3 4 5 $\frac{\text{Parts}}{100 \text{ Million Avg. Con}}$

N
0-5 6-11 12-17 18-23 24- $\frac{\text{km}}{\text{hr.}}$ Wind Speed

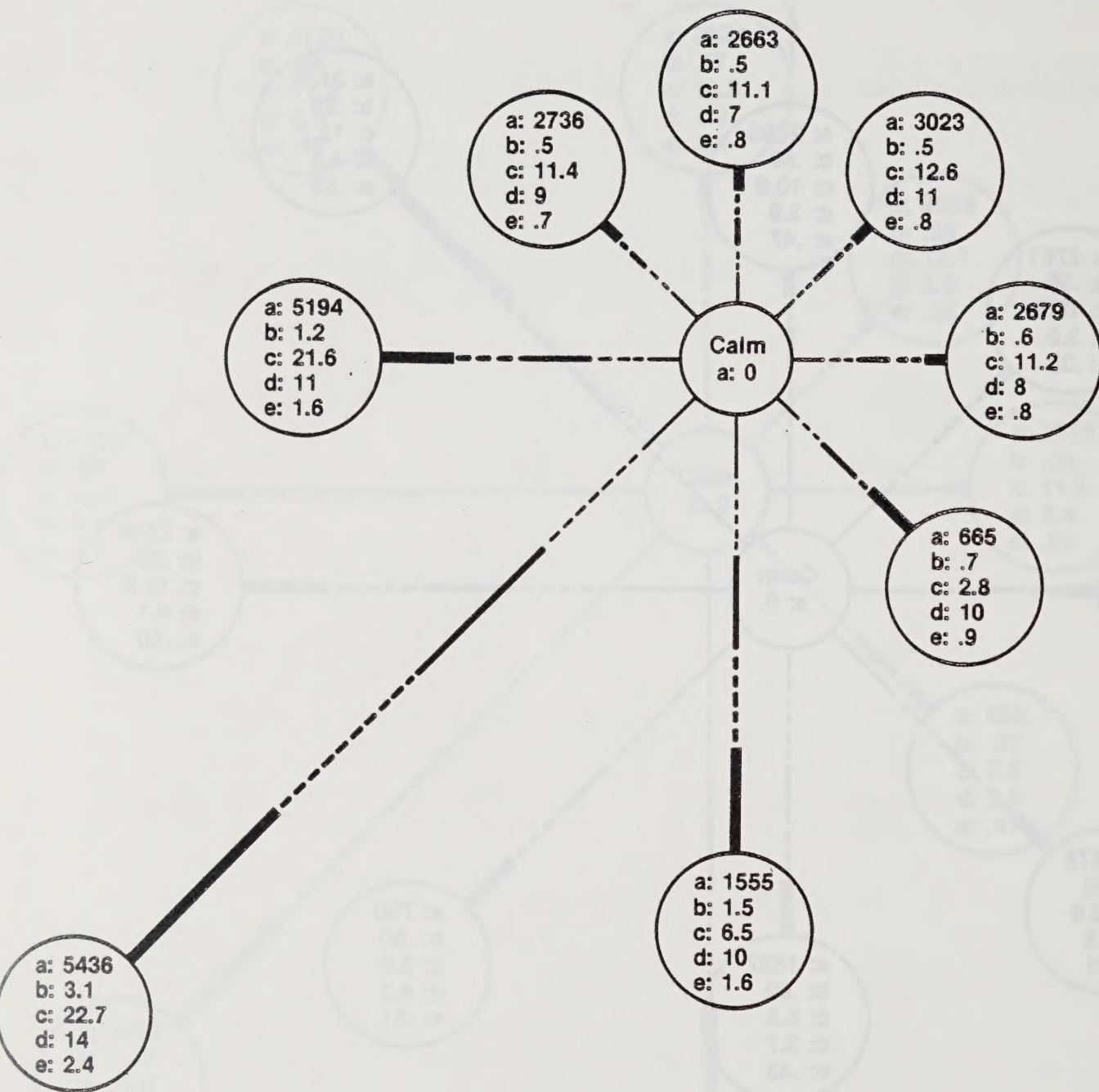


FIGURE 14 - SO₂ pollution rose, based on hourly measurements, for North Park Station, Hamilton, Ontario PERIOD: 1979-81

Total No. of observations (hourly)
Annual average concentration
Percent
Maximum hourly concentration
Standard deviation

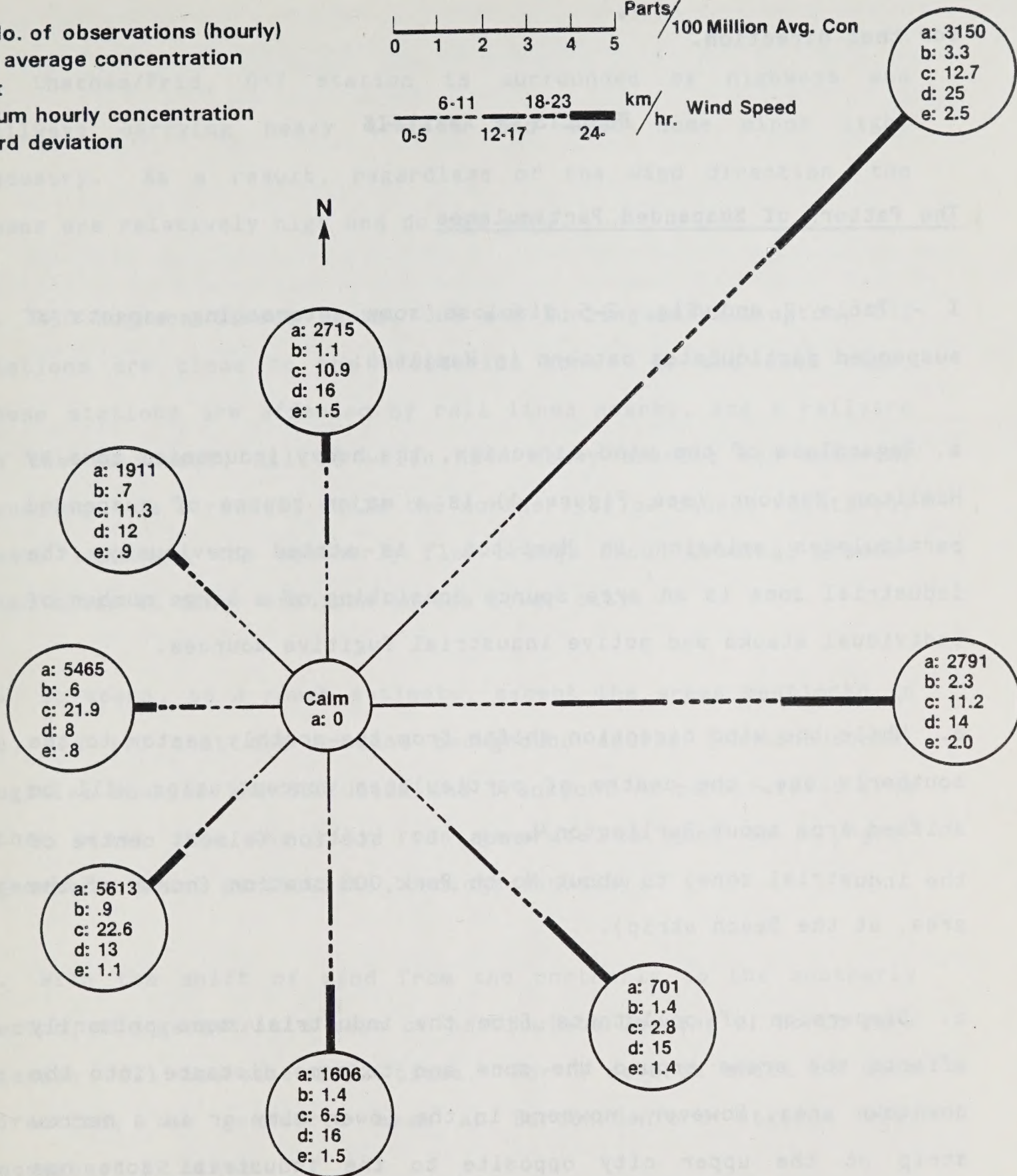
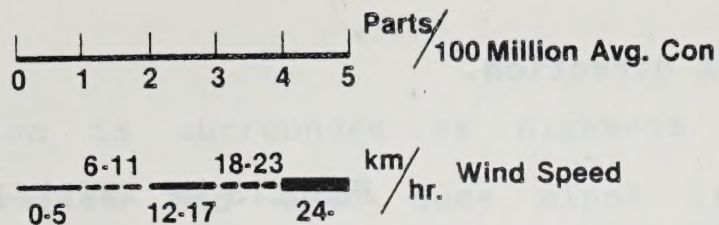


FIGURE 15 - SO₂ pollution rose, based on hourly measurements for Barton/Sanford Station, Hamilton, Ontario PERIOD: 1979-81

for that direction.

RESULTS OF ANALYSIS

The Pattern of Suspended Particulates

I - Table 2 and Fig. 2-5 disclose some interesting aspects of suspended particulates pattern in Hamilton:

a. Regardless of the wind direction, the heavy industrial zone by Hamilton Harbour (see Figure 1) is a major source of suspended particulates emission in Hamilton. As stated previously, the industrial zone is an area source consisting of a large number of individual stacks and active industrial fugitive sources.

b. While the wind direction shifts from the northerly sector to the southerly one, the centre of particulates concentration will be shifted from about Burlington/Leeds, 011 station (almost centre of the industrial zone) to about North Park, 008 station (north of the area, at the Beach strip).

c. Dispersion of pollutants from the industrial zone primarily affects the areas around the zone and to some distance into the downtown area. However, nowhere in the lower city or in a narrow strip at the upper city opposite to the industrial zone has immunity.

d. Chatham/Frid, 017 station is surrounded by highways and railways carrying heavy traffic and also some minor light industry. As a result, regardless of the wind direction, the means are relatively high and do not vary.

e. 450 Hughson Street North, 067 and Burlington/Wellington, 012 stations are close to the industrial zone. At the same time, these stations are affected by rail lines nearby, and a railyard to the southwest, all of which have heavy traffic and material handling. As a result, while the northerly flow causes relatively heavy loadings, the southerly flow brings about loadings greater than those at other stations in the lower city.

f. It seems, to a rough estimate, except the areas mentioned in (d) and (e) that the ambient background source (non-industrial fugitive sources and diffusion and transport of particulates from other areas into the city) can generate as much as $60 \mu\text{g}/\text{m}^3$ (geometric mean) particulate loadings annually .

g. With the shift of wind from the northerly to the southerly sector, the geometric mean of particulate loading of North Park station will increase 2.62 times. For a reverse shift of wind direction, the geometric mean at Barton/Sanford station will increase 1.82 times.

h. In the lower city area, the far east of the city (Red Hill

Creek area) is the least affected by the industrial zone and wind shift.

II - Generally speaking, Table 3 and Fig 6 and 7 also confirm the conclusions already noticed in previous discussion. Although there are some variations, lower city stations 001,007,009,011,025,087,501,502 and 503 all have significant ($P < 0.05$) positive correlation coefficients between N-E wind directions and particulate loadings. The North Park, 008 station which is located to the north of the industrial zone on the Beach strip (see Fig. 1), has significant ($P < 0.05$) negative correlations with these directions. These suggest a relatively high dependency of increased particulate loadings on winds blowing across the industrial zone.

Stations 012 and 067 show significant ($P < 0.05$) positive correlations between NE-E winds and particulate loadings, which is in agreement with Item e of Section I of the discussion of results. Particulate loadings at station 017 have significant positive correlations only with NE-ENE winds. This station is mainly influenced by sources in its vicinity. At station 504, loadings have significant correlation only with ENE winds. As has already been noted, in the lower city, this station is the least affected by the either industrial zone or by wind shift.

Among the stations located in the upper city, Mount Hope, 507 shows no significant positive correlations between particulate

loadings and northerly sector (N-E) winds. In fact, except a narrow strip off the escarpment brow, the rest of the upper city is not usually influenced by the industrial zone. This strip contains stations 085, 508, and 509. However, loadings at these stations, as well as stations 505 and 506, are all influenced positively by winds from other directions as well (see Table 2).

Winds with SW-NW, and particularly with WSW-WNW directions, will generally lead to some significant negative correlations between particulate loadings and flows. These negative correlations tend to be more scattered and less prominent than the positive correlations found downwind from the industrial zone.

However, to sum up the preceding discussion the following general points can be made:

a. In the lower city and a narrow strip of the upper city near the edge of the escarpment and directly south of the industrial zone, particulate loadings at receptors downwind from the industrial zone will generally tend to have significant positive correlations with wind directions.

b. Loadings at receptors upwind from the zone will either have non-significant or significant negative correlations with wind directions.

III - Table 4 and Fig. 8 show that, at the Barton/Sanford station, there is a highly significant ($P < 0.01$) positive correlation coefficient ($r = 0.68$) between winds from the northerly sector and particulate loadings. The negative correlation coefficient ($r = -0.60$) between southerly winds and loadings is also significant at 1% level. Burlington/Leeds station also has highly significant correlation coefficients at 1% level ($r = 0.67$ and -0.54 respectively). These values clearly demonstrate the importance of wind direction on diffusion and concentration of particulates. The importance becomes even more evident when the values are taken into consideration along with means of particulate loadings (Table 2).

On the other hand, while 450 Hughson Street North is also close to the industrial zone, no significant and meaningful correlations between loadings and either northerly or southerly wind sectors do exist ($r = 0.27$ and -0.08 respectively) for it. Considering the location of this station (Figure 1), it becomes clear that a NNW-NE flow (which covers the major part of the selected northerly sector) reaches this station, without passing over the industrial zone or being necessarily affected by dispersion of particulates from the zone. This makes the correlation smaller and reduces the geometric mean to $85 \mu\text{g}/\text{m}^3$ (Table 2). At the same time, a flow from the southerly sector, has to cross over the nearby railways and railyard which have a heavy traffic and material handling. As a result, with a flow

from the southerly sector a relatively high amount of particulates will be loaded at the 450 Hughson St. N. Site ($70 \mu\text{g}/\text{m}^3$ geometric means). Therefore, a correlation similar to those of other two examined sites is not apparent here.

Particulate loadings at the Mountain Police, 085 station have a significant positive correlation at the 5% level with the northerly winds sector, but have a non-significant negative correlation with the southerly winds sector ($r=0.42$ and -0.18 respectively). It has already been noted that with northerly winds, emissions from the industrial zone will more or less penetrate a narrow strip off the escarpment brow opposite to the industrial zone. On the other hand, correlation for the southerly sector indicates that no meaningful relationship exists between winds from that sector and particulate loadings at this station.

Soiling Index and SO_2 Pollution Roses

Soiling index and pollution roses for North Park, 008 and Barton/Sanford, 025 stations (Figure 12-15), also confirm the conclusions of the previous sections. With south to west winds, 008 station has a high loading of fine particles, and the maximum concentration occurs with a southwesterly wind. A flow with this direction crosses the centre of the industrial zone. At this station, north to east flow, or in fact a flow from Lake Ontario, has the lowest loadings. The remaining two directions, i.e., NW,

and SE, which bring the flow from the city complexes (from Burlington and east of Hamilton respectively), have loadings more than those of the Lake Ontario, but much lower than those of the industrial zone.

Station 025, located at the south of the zone, shows the same trend but with a reverse direction. This station has the highest loadings of fine particulates from northeast-east winds (from the heart of the industrial zone), being followed by those from a southeast direction. The lowest concentrations occur with west and northwest winds, while those from the remaining directions have moderate concentration.

With respect to wind speed, it can be noted that on the average, the lowest group of wind speeds (0-5 km/hr) coincides with the maximum loadings. However, it seems that wind speed does not have any apparent effect on the level of pollution, when it is blowing from the directions which coincide with high levels of pollution concentrations (i.e. NE-E for 025, and S-W for 008 station).

In addition to the average concentration, the other values in the circle show that; (a) the prevailing wind directions in the area are southwest and west, followed by northeast and east directions. The least frequent wind is from southeast; (b) there is not any preferred direction for maximum hourly concentration. A burst or a puff of a high level of fine particulates may be

emitted anywhere within the study area; (c) altogether, for levels of high average concentration, the standard deviations become larger, demonstrating a larger variation of values about the mean of the sample. On the contrary, for low concentrations, the standard deviation becomes smaller, indicating a smaller variation of values about the mean.

SO₂ pollution roses (figure 14-15) also show more or less the same trend. Here again, for the North Park station the highest average concentration occurs with flows from south to west, and the maximum is from the southwest direction. For the Barton/Sanford station, the highest concentration is with northeast to east winds, and maximum occurs when winds are from the northeast direction.

Wind speed grouping shows that contrary to fine particulates (soiling index), on the average, low wind speeds do not associate with the highest loadings. In fact, when wind speed is 12-17 km/hr and more, cases of higher loadings, particularly for the directions of high concentrations are increased.

As in the case of soiling index pollution roses, it can be noticed that the prevailing winds are from southwest and west respectively, and the direction of least occurrence is southeast. Maximum hourly concentration does not show a specific trend, though directions of maximum average concentrations (SW for 008 and NE for 025) have also the maximum hourly concentrations.

Values of standard deviations show a large variation in nearly all cases.

Conclusions

Suspended particulates have three sources in Hamilton'

(a) Background source, which is due to the long and medium range diffusion and transport of particulates from other areas into Hamilton region. (b) Non industrial fugitive source(s), which is caused by urban fabric and activities such as traffic and construction. (c) Industrial source, which is an area source to the north of the city, by Hamilton Harbour, and is a combination of stacks and industrial fugitive source(s). In this report, (a) and (b) sources combined have been referred to as "ambient background source".

To a rough estimate, ambient background source can generate and disperse into the urban fabric an annual geometric mean of as much as $60 \mu\text{g}/\text{m}^3$. However, locations adjacent to fugitive sources may have higher loadings. In the city scale, wind direction does not have a great influence on the levels of concentration from this source.

Under favourable wind directions, emissions from the industrial source may add substantial amounts of particulates to concentration levels caused by the ambient background source. The areas in and around the zone will be affected the most by the process.

With winds from the southerly sector (SSE-W), the effluent is mainly transported and dispersed over Hamilton Harbour and Lake Ontario. On the other hand, with winds from the reverse sector (NNW-E), emissions from the zone are mainly transported and dispersed across the lower city and a narrow strip of the upper city near the edge of the escarpment and directly south of the industrial zone. The rest of the upper city has an air pollution pattern of its own. The far east section of the lower city is the least affected by the process.

It appears that the effect of wind direction shift on the diffusion and transport of fine particulates and SO_2 from the industrial zone is, more or less, similar to that of suspended particulates.

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*Three Dark Figures
Making the Weather
In Folk, in Myth, in Legend,
A threefold test.
Shiva, Vishnu, Brahmin.
Father, Son, Holy Ghost.
Body, Mind, Spirit.
Triune, Triumvirate, Tribunal.
One is Isolate
Two is divisive
Three is Peace.
Three is Torment.
Three is Potent.
Power, Power, Power.
Air, Fire, Water.
Three Dark Figures,
Making the Weather.*

Ron Baird, Sculptor